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Red King Crab

Marine Fisheries REVIEW

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On the cover: The underside
of a red king crab, *Paralithodes*
camtschaticus, in Kodiak, Alaska.
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Articles

77(3), 2015

Natural and Manmade Disasters:
Continuing Nemesis for Louisiana, Mississippi, and
Alabama Fishing Communities Pre- and Post-Katrina

Susan Abbott-Jamieson and Palma Inglese 1

Stakeholder Attitudes Toward
Ecosystem-based Fisheries Management

Ayeisha A. Brinson and Kristy Wallmo 17

Evaluation of Fishing Opportunities under Sea Turtle
Interaction Limits—A Decision Support Model for Hawaii-based
Longline Swordfish, *Xiphias gladius*, Fishery Management

Minling Pan and Shichao Li 31

Limited-access Privilege Programs in the Mid-Atlantic Fisheries

Barbara P. Rountree 39

California's Commercial Fisheries: 1981–2012

Cynthia J. Thomson 48

A Socioeconomic Evaluation of a
Network of Deepwater Marine Protected Areas

Larry Perruso, Jeffrey C. Johnson
Paul Baertlein, and Denise H. Johnson 73

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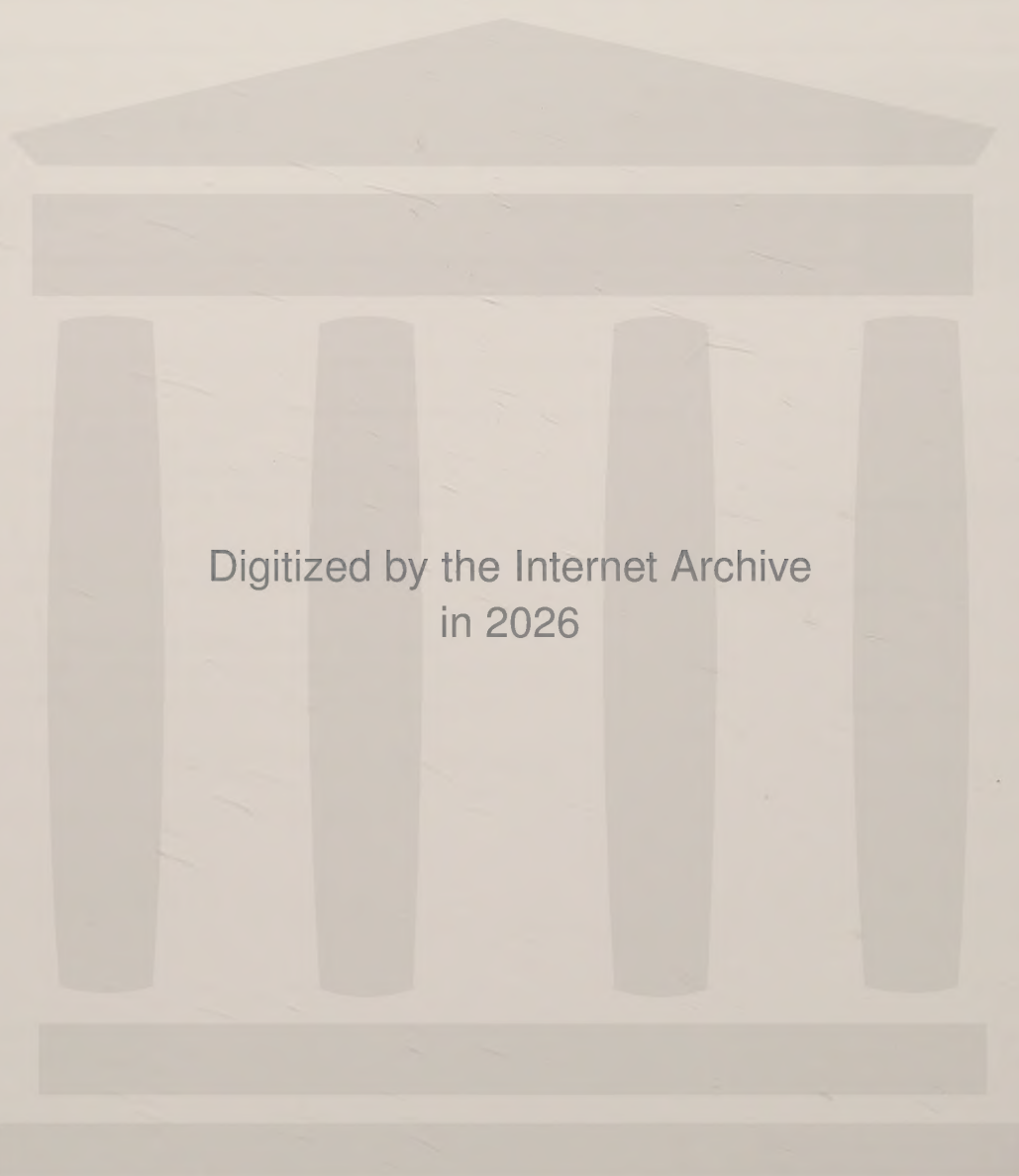
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Alaska Fisheries and Global Trade: Red King Crab, <i>Paralithodes camtschaticus</i> ; Sockeye Salmon, <i>Oncorhynchus nerka</i> ; and Walleye Pollock, <i>Gadus chalcogrammus</i>	Michael Dalton and Jean Lee 84
---	--------------------------------

Extended Abstracts

Excess Harvesting Capacity in Federally Managed Commercial Fisheries: Results from Two U.S. Reports	Joseph Terry and Minling Pan 91
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Economics and the Endangered Species Act: Critical Habitat Designation for Pacific Northwest Salmon and Steelhead	Mark L. Plummer 93
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Natural and Manmade Disasters: Continuing Nemesis for Louisiana, Mississippi, and Alabama Fishing Communities Pre- and Post-Katrina

SUSAN ABBOTT-JAMIESON and PALMA INGLES

Introduction

Gulf of Mexico (GOM) fisheries are among the nation's most productive and diverse. As long as people have inhabited the coastal areas of Texas, Louisiana, Mississippi, Alabama, and the west coast of Florida, fishermen have made their living and enhanced their families' diets through harvesting the abundant marine resources in the region's bayous and waterways. Today both commercial and recreational fishermen pursue diverse species including shrimp, e.g., *Penaeus* spp.; reef fish such as grouper, *Serranidae* spp.;

red snapper, *Lutjanus campechanus*; black drum, *Pogonias cromis*; and amberjack, *Carangidae* spp.; Spanish, *Scomberomorus maculatus*, and king, *Scomberomorus cavalla*, mackerel; shark, e.g., *Carcharhinus* spp.; blue crab, *Callinectes sapidus*; oysters, *Crassostrea virginica*; and menhaden, *Brevoortia patronus*.

The GOM region is also a major source of the nation's oil and gas resources. According to the U.S. Energy Information Administration¹, in 2012 federally-leased GOM offshore leases accounted for 23% of U.S. crude oil production and 7% of total U.S. dry production. The region is also home to more than 40% of the total U.S. petroleum refining capacity and 30% of the total U.S. natural gas processing plant capacity.¹ The GOM petroleum and natural gas industries have been an important aspect of the region's overall

economy and human and natural ecosystem for several decades beginning in Texas and Louisiana in the 1930's and moving east to include Mississippi and Alabama by the 1970's and 1980's. So far, Florida is not involved with the petroleum industry.

Fishermen also work in the petroleum industry, and petroleum workers often fish commercially and recreationally. Oil rigs can become aggregations of marine life, and they can also be the source of their destruction.

Likewise, the GOM is a high-risk region for damaging tropical storms and hurricanes. Major hurricanes in the last decade include Ivan in 2004; Dennis, Katrina, Rita, and Wilma in 2005; Gustav and Ike in 2008; and Isaac in 2012. The worst of these storms, Hurricane Katrina, damaged Florida, Alabama, Mississippi, and Louisiana, but its worst fury struck an area stretching from Lafourche Parish in eastern Louisiana west of New Orleans to Baldwin County in Alabama.

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¹U.S. Energy Information Administration, Gulf of Mexico Factsheet, <http://www.eia.gov/special/gulfofmexico/>, accessed 16 August 2013.

ABSTRACT—On 29 August 2005, Hurricane Katrina came ashore devastating coastal communities in the northern Gulf of Mexico. As the storm crossed the wetlands south of New Orleans boats were sunk, houses and businesses were destroyed, and lives were drastically changed. Hurricane Katrina happened at a time when the region's fishing industry was already facing economic hardship. It marked the beginning of a series of major calamities between 2007 and 2012 including three more hurricanes, a major Mississippi River flood, a major recession, and the Deepwater Horizon (DWH) oil spill that have continued to challenge the fishing industry in the Gulf of Mexico. The paper begins with a detailed examination of Hurricane Katrina's damage to fishing infrastructure in fishing communities in Lou-

isiana, Mississippi, and Alabama that were followed for nine months post-Katrina as part of a NMFS-funded social impact assessment (SIA). Next the paper highlights the major natural and manmade disasters that have affected marine fisheries in Louisiana, Mississippi, and Alabama between 2005–12. The impacts of this series of disasters are examined as they relate to 1) changes in population between 2000–10 in the fishing communities originally followed in the post-Katrina SIA, 2) changes in numbers of processing plants and processing plant employees between 2003–12, and 3) changes in pounds landed and their value as reported by NMFS for Louisiana, Mississippi, and Alabama during the same period. Although the area as a whole has lost population, some fishing communities have lost significantly more, particularly

Louisiana, while some, in Alabama and Mississippi, have gained. There has been an overall decline in both numbers of processors, wholesalers, and their employees during the period examined; the 2004–07 period coinciding with repeated hurricanes shows the sharpest declines. Pounds of fish landed, while impacted by hurricanes and the DWH oil spill, rebounded by 2011–12 to their highest level since 2003; their highest value occurs in 2011–12 as well. The fishing industry in these states as measured by pounds and value of landings has shown an ability to recover from the shock of hurricane damage and oil spill closures over the past decade, but the longer-term economic downward trends measured by numbers of processors, wholesalers, and their employees remain unchanged.

This paper first describes damage to commercial and recreational fishing infrastructure in a set of local fishing communities that received the greatest impact from Hurricane Katrina, comparing data on initial losses to their subsequent state of recovery nine months later in May 2006. It then highlights a series of natural and manmade disasters that have further impacted these areas between 2006 and 2012. We conclude with general observations on conditions in 2012—seven years after Katrina. To begin the story, an overview of the condition of the GOM fisheries prior to the storm will set the stage.

The GOM Fisheries Before Hurricane Katrina

The Gulf's commercial fishing industry has long been subject to international, national, and regional economic and social influences, and national and state regulatory impacts. It was in flux before Hurricane Katrina² (Ingles, 2008).

The steady rise in the cost of marine diesel fuel since 1970 was having a significant impact. Nationwide, the average price for marine diesel fuel increased from \$1.11 per gallon in 1995 to \$1.81 per gallon in 2004, a 61.3% increase in the decade prior to Katrina. Marine diesel fuel is the only fuel used to power commercial fishing vessels (IAI²:13; Travis and Griffin³: 3), and the rising price had increased the cost of harvesting the Gulf's marine resources.

With favorable loans from banks and boat manufacturers in the 1990's, some commercial fishermen bought large shrimp trawlers with electric

freezers taking on "...big notes for big boats...", as one fisherman in Grand Isle, La., commented.⁴ In 2005, a new shrimp trawler 80 ft in length with a steel hull could cost \$700,000–\$800,000, not including essential equipment. The price of the booms, nets, and electronics to outfit these new fishing vessels and refurbish others was also steadily increasing.

Imported, farm-raised shrimp have gained a significant market share in the domestic U.S. marketplace in the last two decades. By 1996, only 21.3% of the federally permitted U.S. supply of shrimp was caught in U.S. waters (NMFS, 2001:83). The percentage of U.S. caught shrimp continued to decline each year between 2000 and 2004, when it stood at 11.1% (NMFS, 2008:71). By 2005, a year later, it was only 9.8% of the U.S. supply of shrimp (NMFS, 2008:71).

Within the U.S. shrimp fishery, the GOM shrimp fishery was dominant. Slightly more than 82%, or 214.4 million lbs (heads on), of the domestic shrimp landed in the United States in 2005 were landed in the Gulf of Mexico. The value of the Gulf shrimp was over \$356 million.

The major season for Gulf shrimp-ing is June through September, so it was nearing its end when Katrina struck in late August 2005 (Fig. 1). Competition from imported seafood began affecting the price paid at the dock for local seafood—a particularly serious problem in the shrimp fishery. Price competition from imported shrimp resulted in declining dock prices paid for wild shrimp (IAI²:10–12; Travis and Griffin³). In 2004, shrimpers commented during an interview that by the time they paid for fuel and other supplies, and paid their crew, they earned less than their total expenses.^{4, 5}

As dock prices for shrimp fell, it became harder for the owners of larger vessels to pay the bank notes and also afford the fuel for a long fishing trip. Throughout the Gulf, shrimp boats could be seen tied up at the docks, sometimes in groups of three, four, or five, no longer working. Banks began repossessing boats. By the summer of 2005, few banks were financing new commercial fishing boats or even providing loans for maintenance and repairs.⁶

To try to offset increasing costs and declining revenues, some boat owners began to limit or delay boat maintenance. They also began dropping boat insurance, whose cost had also been rising steadily during the same period (Travis and Griffith³:6). Some Louisiana shrimp dealers commented to an interviewer that some of those fortunate enough to own and operate smaller, more fuel-efficient boats that fished closer to shore were beginning to alter their fishing strategy by returning to the docks after only a few days instead of staying out for several days. Fishermen said they used this strategy so they could buy less fuel for each trip, requiring less cash output. They further commented that captains were also reducing the number of crew hired on their vessels and relying more on labor from family members. Despite these adaptations, many shrimpers recognized that no matter what cost saving measures they employed, the cost of fuel coupled with the low price paid for shrimp at the dock was going to eventually put many of them out of business.⁷

Management measures on all types of fishing in 2005 included marine protected areas that restricted fishing, gear restrictions such as the turtle exclusion devices for shrimp nets, re-

²The following description, unless otherwise noted, is based on the "Preliminary Assessment of the Impacts of Hurricane Katrina on Gulf of Mexico Coastal Fishing Communities," Final Tech. Rep. prepared for NMFS by Impact Assessment, Inc., released in 2007 (<http://sero.nmfs.noaa.gov/sf/socialsci/pdfs/FINAL-PUB-LIC-N.pdf>) accessed 9 Dec. 2013.

³Travis, M. D., and W. L. Griffin. 2004. Update on the economic status of the Gulf of Mexico commercial shrimp fishery. April 5, 2004. Rep. SERO-Econ-04-01, NMFS Southeast Reg. Off., St. Petersburg, Fla., 13 p. (<http://sero.nmfs.noaa.gov/sf/socialsci/pdfs/EconUpdateGulfShrFinal.pdf>) accessed 9 Dec. 20013.

⁴Notes from interviews conducted by Palma Ingles (bunnypevas@hotmail.com) for NMFS with fishermen and processors in Grand Isle, La., August 2006.

⁵Also see Travis and Griffith (footnote 3) who corroborate the general decline in the commercial shrimp industry.

⁶Notes from interviews conducted by Palma Ingles (bunnypevas@hotmail.com) for NMFS with fishermen and processors in Grand Isle and Empire-Venice, La., August 2006. Travis and Griffith (footnote 3) point out the particular problems of high-operating-cost larger vessels.

⁷Notes from interviews conducted by Palma Ingles (bunnypevas@hotmail.com) for NMFS with fishermen and processors in Grand Isle and Empire-Venice, La., August 2006.



Figure 1.—Commercial shrimp vessels, Grand Isle, La., before Hurricane Katrina, July 2004. Photo: Palma Ingles.

duced trip limits, and closed seasons. The cumulative effects of these restrictions added hurdles for Gulf commercial fishermen. Individual fishermen's ability to switch from one fishery to another as an adaptation to changes in management regime was also becoming more difficult due to new regulations, though historically this had been a common coping strategy among commercial fishermen.

The Gulf's processing sector handles a combination of fish harvested locally and from other U.S. regions, as well as imported fish. The Gulf processing sector supplies the U.S. domestic table, some export trade, and they produce fish oils and fishmeal from menhaden, *Brevoortia patronus*. This sector was also undergoing change throughout this period.

The number of processors of all sizes⁸ in Louisiana, Mississippi, and Alabama declined 28.5% from 239 in 1998 to 171 in 2004. Employment

declined 8.3%, from 6,761 to 6,200 persons, reflecting the smaller number of processors (NMFS, 2000:95; 2005:82). The total value of processed products was similarly patterned. In 2004 the value of processed seafood products for Louisiana, Mississippi, and Alabama combined was \$860 million, 12% lower than the 1998 value of \$980 million.⁹

In contrast to the commercial fishing sector, the saltwater recreational fishing sector was steadily expanding over the same period as part of the area's vibrant recreational industry. Saltwater recreational fishing trips increased 79% in Louisiana, 32% in Mississippi, and 111% in Alabama between 1998 and 2004. The number of non-resident anglers increased 68% in Louisiana and 247% in Alabama, while Missis-

issippi attracted fewer out of state marine anglers, their numbers declining 33%.^{9,10}

Finally, the population along the GOM coast from Terrebonne Parish west of New Orleans, La., to Baldwin County, Ala., on the Florida state line, had increased about 9% between 1990 and 2004. The greatest growth occurred in the contiguous areas stretching from St. Tammany Parish, La., on the Mississippi state line, through Baldwin County, Ala. Estimated population increases during this period were 48% for St. Tammany Parish, 16% for Mississippi's Hancock, Harrison, and Jackson Counties combined, and 14% for Mobile and Baldwin Counties combined in Alabama.¹¹

¹⁰ The long decline in the number of out of state saltwater anglers visiting the Mississippi coast may reflect the expansion of the gaming industry as the more important draw to this section of the Gulf coast. Saltwater anglers are picking other destinations in increasing numbers.

¹¹ U.S. Census estimated population tables (<http://www.census.gov/popest/data/historical/index.html>).

⁹ NMFS Processed Product Annual Survey (unpubl. data); all values are calendar year values. Data available from NMFS Office of Science and Technology, Division of Fisheries Statistics, 1315 East West Hwy., Silver Spring, Md. 20910 (<http://www.st.nmfs.noaa.gov/commercial-fisheries/index>).

⁸ This figure excludes catfish, *Ictalurus punctatus*, processors.

Gentrification pressures were also beginning to turn real estate previously dedicated to commercial fishing uses into real estate for vacationers, retirees, and others who wanted to live near the water with easy access to recreational docks and marinas, shopping, dining, and other forms of entertainment. This further squeezed the commercial fishing industry. The area of greatest population growth was coterminous with Katrina's zone of worst damage.

GOM Topography and the Threat of Hurricanes

Fishing communities develop in areas where there is easy access to marine resources. As a consequence, in the GOM this inevitably exposes fishing communities to hurricanes because the topography that characterizes most coastal regions of the Gulf is low-lying. The continuing loss of barrier islands, sand dunes, and wetlands in the GOM region has left many coastal communities even more vulnerable to hurricanes' triple threats of hurricane-generated storm surges, rain-caused flooding, and high winds. Extensive levee systems were erected over many decades to try to reduce the risk to local communities from the surrounding water during storms. Attachment to an ecologically distinctive place, often generations-deep with dense social networks, and easy access to some of the best fishing grounds in the country entice local residents to continue living in these coastal areas despite the obvious risk posed by severe storms.¹²

Fishermen who have grown up along the GOM coast tell stories about big hurricanes in the past. The unnamed hurricane that struck Galveston in 1900 killed at least 8,000 people, Hurricane Audrey killed 390 in 1957, Hurricane Betsy killed 75 in 1965, and Hurricane Camille killed 143 in 1969.

¹²See Tootle (2007) for a similar discussion of the social and cultural factors keeping long-term residents of southwest Louisiana attached to place, following traditional wetlands occupations in the context of describing that part of Louisiana's recovery from Hurricane Rita's devastation three weeks after Katrina.

Everyone understood that a hurricane of Katrina's magnitude could eventually hit the northern GOM.

Research on Gulf Communities

The NMFS Southeast Regional Office (SERO) began conducting preliminary research to identify communities associated with the fishing industry in all five states that border the GOM—Texas, Louisiana, Mississippi, Alabama, and Florida's west coast in 2002.¹³ The final set of fishing community reports for Louisiana, Mississippi, and Alabama had just been completed as Katrina began to form in the Atlantic.¹⁴ Additional in-depth research was also being conducted during the same period in a subset of these communities by one of the authors, Palma Ingles, then a SERO staff anthropologist (Ingles and McIlvaine-Newsad, 2007; Ingles, 2008).

After Hurricane Katrina completed its destruction, NMFS immediately hired contractors to return to 38

¹³NMFS conducts sociocultural and socioeconomic research on Gulf of Mexico fishing communities to comply with National Standard 8 of the Magnuson Stevens Act (MSA). The MSA requires fishery managers to consider the social and economic impacts on fishing communities when considering new regulations. The NMFS Southeast Regional Office has been conducting research as part of NS 8 requirements since 2002. One goal of this research is improved understanding of the role that commercial, recreational, and subsistence fishing play within the communities. Documenting the effects of Hurricane Katrina on the fishing industry was part of this work.

¹⁴IAI. 2005a. Identifying communities associated with the fishing industry in Louisiana. Final Tech. Rep. prep. for the NMFS Southeast Reg. Off. under Contr. WC133F-02-SE-0297, 617 p. (<http://sero.nmfs.noaa.gov/sf/SocialSciencePublications.htm>) accessed 9 Dec. 2013; IAI. 2005b. Identifying communities associated with the fishing industry in Mississippi and Alabama. Final Tech. Rep. prep. for the NMFS Southeast Reg. Off. under Contr. WC133F-02-SE-0297, 274 p. (<http://sero.nmfs.noaa.gov/sf/SocialSciencePublications.htm>) accessed 9 Dec. 2013; IAI. 2005c. Identifying communities associated with the fishing industry along the Florida Gulf Coast. Final Tech. Rep. prep. for the NMFS Southeast Reg. Off. under Contr. WC133F-02-SE-0298, 695 p. (<http://sero.nmfs.noaa.gov/sf/SocialSciencePublications.htm>) accessed 9 Dec. 2013; IAI. 2005d. Identifying communities associated with the fishing industry in Texas. Final Tech. Rep. prep. for the NMFS Southeast Reg. Off. under Contr. WC133F-03-SE-0603, 413 p. (<http://sero.nmfs.noaa.gov/sf/SocialSciencePublications.htm>, accessed 9 Dec. 2013.

of the communities that they had just profiled in the affected areas of Louisiana, Mississippi, and Alabama to conduct a preliminary assessment of storm impacts on fishing infrastructure (IAI²). Three visits were made to each community over nine months through May/June 2006 to document the recovery of fishing infrastructure and the fishing industry. Subsequently, additional visits were made to Grand Isle, Jefferson Parish, and the Empire-Venice area of Plaquemines Parish, La.; to the Gulfport-Biloxi area, Miss.; and to Bayou La Batre, Ala., by SERO researchers to continue to follow recovery efforts in these communities. The following assessment is drawn from this research.

Katrina's Devastation

Hurricane Katrina came ashore on 29 August 2005, in Louisiana obliterating or severely damaging coastal communities from 70 miles west of New Orleans, La., to Mobile Bay, Ala. (Fig. 2). Katrina ended lives and destroyed homes, churches, schools, hospitals, and doctors' offices, grocery stores, and other businesses, as well as roads and bridges, water and sewage systems, and phone and power distribution infrastructure leaving behind debris piled 30 ft high in places where people once lived and worked. Entire forests far inland were killed, leaving trees smashed and dying in pooling water from the hurricane's heavy rains.¹⁵

The Gulf's oil and gas industry's refining and pumping capacity were seriously damaged, affecting both the national price and availability of gasoline and diesel. Hundreds of thousands of people evacuated from their coastal homes, many temporarily relocating to other communities within the region. Many former residents did not return. As of 2014, Katrina remains the most costly hurricane in U.S. history, re-

¹⁵Research by Chambers et al. (2007) documents the loss of vast forest tracks in Mississippi and Alabama to the combined effects of Katrina and Rita, characterized by Kaufman (2007) as the "largest single forestry disaster on record in the nation...that killed or severely damaged about 320 million trees."

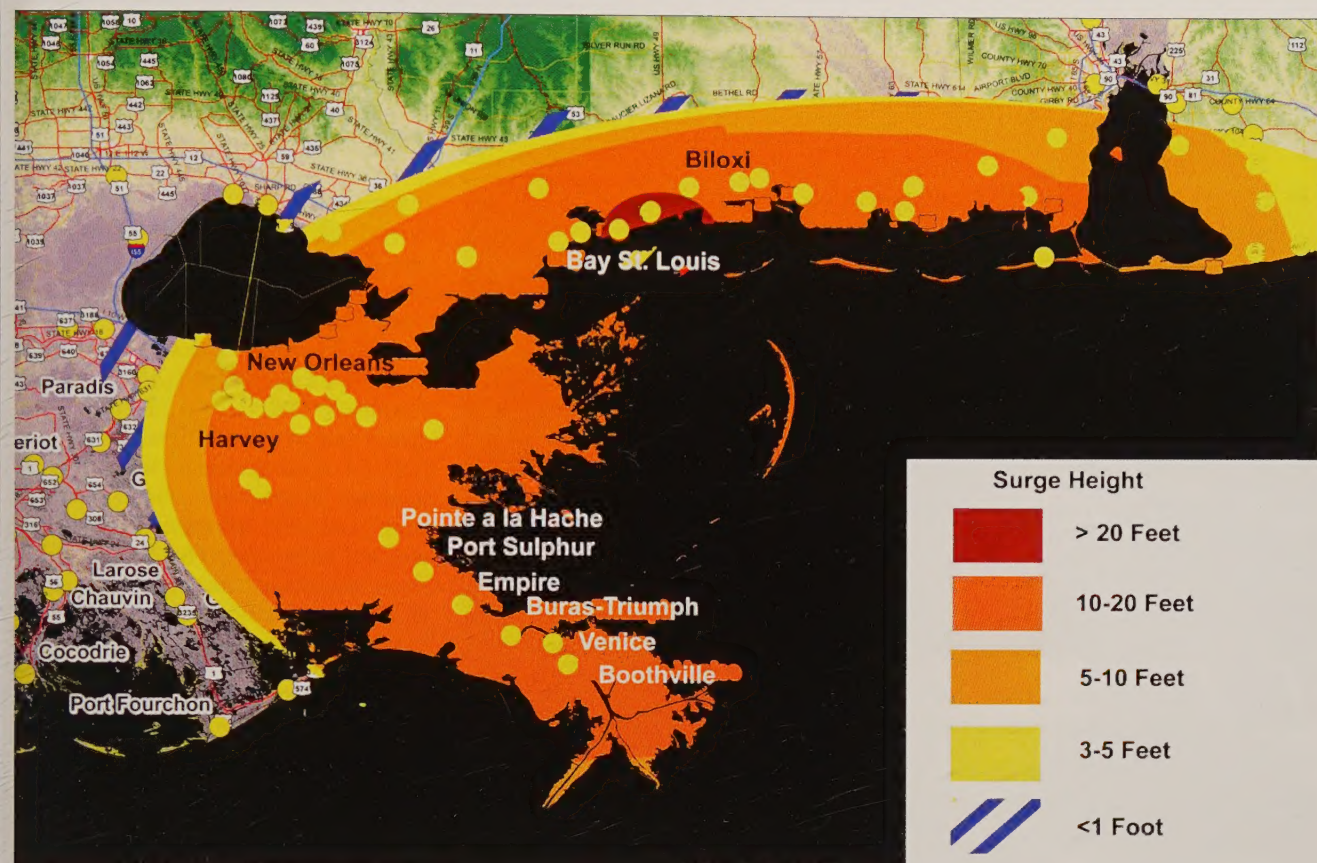


Figure 2.—Katrina tidal surge and flood elevations, and community locations (dots). Map: IAI graphic.

sulting in the largest loss in the entire history of the insurance industry with more than \$41.1 billion paid by private companies across six states and the government to settle claims (Fig. 3).¹⁶

Hurricane Katrina severely crippled the commercial fishing industry in the most heavily impacted areas in the storm's path, leading the U.S. Department of Commerce to issue a "fishery failure and fishery resource disaster declaration" for the GOM.¹⁷ The storm had sunk, stranded, or damaged thousands of boats of all sizes and descriptions—from commercial and recreational fishing boats to tug-

boats and barges that blocked waterways and roads, lay on levees, or were washed into surrounding marshes and bayous. Sunken boats and storm debris choked waterways making marine navigation difficult.

Many fish processing plants were severely damaged or completely destroyed along with ice plants, commercial docks, gear repair and supply businesses, ship building and repair facilities, and all the other support business that the commercial fishing industry needs to operate. Oyster beds were destroyed in Mississippi and damaged in other areas.

Everyone worried about pollutants that may have escaped into marine waters from the oil industry, industrial chemicals, and untreated sewage, further damaging marine resources. Surviving commercial vessels began shifting their effort to the east and to

the west, to less damaged areas, to find support services, including fuel, and places to off-load their catch.

Businesses and infrastructure that supported recreational fishing met a similar fate (Fig. 4). Recreational marinas, docks, and fishing piers were washed away in some areas. In the worst hit areas, the only hotels still able to operate immediately after the storm soon filled with emergency and construction workers supplanting salt-water anglers and other tourists, while destroyed restaurants were replaced with canvas-covered feeding stations handing out military Meals Ready to Eat (MRE's). As the nation began to recognize the extent of the devastation, trip cancellations poured in, even though many charter boat operators had been able to protect their boats by moving them out of harm's way before the storm hit.

¹⁶Insurance Information Institute, Top 10 Most Costly Hurricanes in the United States (thru 2014) (<http://www.iii.org/fact-statistic/hurricanes>) accessed 27 Oct. 2015.

¹⁷Announced 9 Sept. 2005. See <http://www.publicaffairs.noaa.gov/releases2005/sep05/noaa05-112.html>, accessed 16 Aug. 2013.



Figure 3.—Stairway to nothing is all that remains of a once substantial home in the Long Beach area of coastal Mississippi after Katrina, Oct. 2005. Photo: Palma Ingles.



Figure 4.—Destroyed equipment, Back Bay area, Biloxi, Miss., Oct., 2005. Photo: Palma Ingles.

The next three sections present a detailed examination of Katrina's impact on fishing infrastructure in Louisiana, Mississippi, and Alabama.

Louisiana

Louisiana has 397 miles of coastline, the longest of the three most affected states. In 2004, the volume of commercial landings by pounds ranked second in the nation with only Alaska reporting more landings, while the dollar value of the landings ranked fourth (NMFS, 2005). In 2006 Louisiana still retained its relative position for both landings and value of landings despite the extensive hurricane-generated infrastructure damage detailed below (NMFS, 2007b). Louisiana also has a substantial recreational fishing industry.

Louisiana's fishing infrastructure was devastated in the worst hit areas in Terrebonne Parish west of New Orleans through St. Tammany Parish on the Mississippi state line; other areas further to the west received less damage.¹⁸ Sixty-six percent of Louisiana's shrimp fishermen lived in areas affected by Hurricane Katrina. Eighty-three percent of Louisiana's seafood processors and all eight seafood canning factories were also located in these areas (IAI²).

Table 1 shows the baseline counts of different categories of commercial and recreational fishing infrastructure and services observed in specific fishing communities in the worst hit areas by field teams in October 2004 as part of NMFS' fishing community profiling work. Initial post-storm visits to these communities about one month after Hurricane Katrina revealed the total or near-total loss of everything from commercial docks, processors, and ice houses to recreational docks and marinas—very little was left.

Commercial and for-hire vessel operators with operational fishing vessels were able to resume fishing or begin working for federal contractors to help

¹⁸Hurricane Rita's damage to western Louisiana and eastern Texas are not included in this paper. See footnote 12.

clear blocked waterways shortly after the storm had passed. Many had been able to protect their vessels from the storm by moving into the state's extensive bayou system as the storm approached. Those who could resume fishing soon after the storm passed usually moved their vessels further west to places such as Houma, Terrebonne Parish, where off-loading and other support facilities were still available. As offloading docks were rebuilt by early spring of 2006 in places such as Grand Isle and Venice, fishermen began returning to their original home-ports to unload their catch.

By May 2006, recovery efforts were underway throughout the area. Two-thirds of the boat yards were back in some degree of operation, often serving as staging areas for salvaged boats waiting for repair or destruction, and about 25% of the area's commercial docks were available for use; only 3 ice houses out of 18 were operating, constituting a serious problem for commercial fishermen who required ice to preserve their catch. By mid-June 2006 the state's three menhaden processing plants were all operating again, helping to sustain the state's relative rank in commercial landings (NMFS, 2005, 2007a, 2007b).¹⁹

By July/August of 2006, less damaged communities such as Grand Isle were further along in the recovery process than those that had been nearly totally obliterated. Parts of Venice had remained under water for a month after the storm, and in the summer of 2006 the community still looked little different than it had in October 2005, a few months after the storm.

Insurance covered few of the hundreds of commercial fishing boats that were lost (Fig. 5), and according to some local dealers many fishermen began using their own resources to recover and repair their boats or buy new ones so they could reenter

Table 1.—Louisiana¹ fishing infrastructure damage 2004–06.²

Infrastructure or Service	Count			Loss	
	2004 Oct	2005 Oct	2006 May	% Loss Oct 2005 from 2004 baseline	% Loss May 2006 from pre-storm baseline
Boat yards/boat builders (recreational/commercial)	9	3	6	-66.7%	-33.3%
Commercial docks /off loading facilities (in LA includes dealers who own the dock)	53	2	13	-96.2%	-75.5%
Net makers	13	0	0		
Fishing gear, electronics, welding, other repair	14	0	0		
Fish processors, wholesale fish house	7	0	0		
Ice houses	18	0	3		-83.3%
Seafood transport/trucking operations	29	0	0		
Fishing pier	4	0	0		
Recreational docks/marinas/boat ramps	45	1	8	-97.8%	-82.2%
Bait & tackle/fishing supplies	20	1	3	-95.0%	-85.0%
Seafood retail markets	15	0	0		

Grand Isle, Boothville, Buras-Triumph, Empire, Venice, Pointe à la Hache, Port Sulpher, Chalmette, Delacroix, Hopedale.

²Data source: Preliminary assessment of the impacts of Hurricane Katrina on Gulf of Mexico coastal fishing communities. DOC/NOAA/NMFS, Mar. 2007. <http://sero.nmfs.noaa.gov/st/socialsci/pdfs/FINAL-PUBLIC-N.pdf>, accessed 8 Dec. 2013.



Figure 5.—Smashed commercial fishing boats pinned against the Empire, La., bridge, still unmoved Aug., 2006. Photo: Palma Ingles.

the fishing industry.^{7,20} Recreational fishing tournaments had resumed and infrastructure was being rebuilt to support the recreational and charter fishing industry in some communities, such as Grand Isle and Venice. Recreational saltwater anglers could stay in New Orleans where hotels were becoming available, and then drive to a

recreational marina or dock in other communities that had yet to rebuild their hotels and restaurants.⁷ Nonetheless, recreational fishing trips decreased by 11% in Louisiana between September 2005 and August 2006 (NMFS, 2007c:43).

Some shrimp dock owners reported in June 2006 that they were having difficulty selling the shrimp that was being brought in because so many Louisiana shrimp processors had been

¹⁹The three plants are located in Empire, Abbeville, and Cameron. The Cameron plant was damaged by Hurricane Rita (http://www.st.nmfs.noaa.gov/st1/market_news/menhaden_forecast_2007.pdf) p. 1-2, accessed 11 Feb. 2013.

²⁰Also see IAI (footnote 2), p. 128–130, for a description of local response and adaptation to Katrina's impact.

destroyed. Some processors were still trying to rebuild, but others had not reopened by summer of 2006. One dock owner interviewed in Grand Isle, La., in June 2006 said that he was sending shrimp to Biloxi, Miss., to be processed by one of the few processors there that had rebuilt. He believed that because so much shrimp were being sent to the Biloxi processor, shrimp prices were further depressed affecting both dealers and fishermen. Despite good catches of shrimp, the adverse economics of the industry continued to impact the surviving fishermen.²¹

By the end of 2006, total pounds of fish products processed in the state had decreased 13% to 401.7 million lbs from their 2004 level of 463.9 million lbs, while the overall value of these products had increased 4% from \$353 million to \$366 million. The increase in value, despite the reduction in total poundage, is likely due to the reduction of menhaden processing in Louisiana while those plants were being repaired.²² The overall value of processed fish products in 2006 (\$366 million) was 8% less than the 1998 value of \$396 million, and the total pounds processed in 2006 was 9% less than the 443.4 million lbs processed in 1998.⁹

Mississippi

Mississippi's three coastal counties share a 44 mile coastline. A substantial fish processing industry had concentrated major facilities in the Gulfport/Biloxi/D'Iberville area prior to 2005, sharing the limited coastal area with an expanding gambling industry, which was required by state law to be off shore on floating facilities. Gulfport, west of Biloxi, is a major shipping container port, while the state's oyster reefs and oyster processing facilities were concentrated further to the west toward the Louisiana state

Table 2.—Mississippi¹ fishing infrastructure damage 2004–06.²

Infrastructure or Service	Count			Loss	
	2004 Oct	2005 Oct	2006 May	% Loss Oct 2005 from 2004 baseline	% Loss May 2006 from pre-storm baseline
Boat yards/builders (commercial/ recreational)	6	0	1		-83.3% ^b
Commercial docking/off loading facilities	16	5	8	-68.8%	-50.0%
Net makers	2	0	1		-50.0%
Fishing gear & electronics/welding/other repair	9	0	4		-55.6%
Fish processors/wholesale fish house	44	3	14	-93.2%	-68.2%
Seafood transport/trucking operations	2	1	1	-50.0%	-50.0%
Fishing piers	14	2	2	-85.7%	-85.7%
Recreational docks/marinas/boat ramps	26	9	13	-65.4%	-50.0%
Bait & tackle/fishing supplies	13	0	0		
Seafood retail markets	18	1	4	-94.4%	-77.8%

¹Waveland, Bay St. Louis, Pass Christian, Long Beach, Gulfport, Biloxi, D'Iberville.

²Data source: Preliminary assessment of the impacts of Hurricane Katrina on Gulf of Mexico coastal fishing communities. DOC/NOAA/NMFS, Mar. 2007 (<http://sero.nmfs.noaa.gov/st/socialsci/pdfs/FINAL-PUBLIC-N.pdf>) accessed 8 Dec. 2013.

line. Recreational marinas, fishing piers, and docks were located along most of the coastline and up its rivers and inlets. Katrina pushed storm surges, estimated at as much as 30 ft high, inland along the western half of Mississippi's coast. The worst hit areas were scoured clean of structures, leaving only pilings of docks and bridges and twisted metal for processing facilities. High winds and flooding from the storm's deluge of rain added to the damage further inland.²³

Table 2 provides the baseline counts of infrastructure types and service categories in assessed fishing communities for October 2004, as well as the post storm counts in October 2005. Devastation similar to Louisiana's was observed by the field teams. The area experienced an 85–100% loss of commercial and recreational boat yards, commercial and recreational gear and repair services, seafood processing plants of all sizes, fishing piers, and retail outlets depending on location (Fig. 6). Very heavy losses, ranging from 50% to nearly 70%, occurred to seafood transport/trucking operations, commercial docking and off-loading facilities, and recreational docks, marinas, and boat ramps.

By May 2006, some rebuilding was occurring; 50% of the commercial and recreational docks and off-loading fa-

cilities and seafood trucking operations had resumed operation, and some of the other services such as boat and equipment repair and retail seafood markets were beginning to reopen. But other infrastructure and support services for the charter and recreational fishing sector such as fishing piers, boat ramps, and bait and tackle shops were yet to be repaired or replaced.

Some of the coastal land that had supported fishing infrastructure before the storm in the Gulfport and Biloxi area was being sold to developers who were beginning to rebuild and expand the casino industry, helped by a post-storm change in Mississippi state law permitting construction of gambling facilities up to 800 feet inland from the shoreline. By summer 2006, just over 30% of Mississippi's processors and wholesale fish houses were again operating, but not necessarily in the same locations. In some cases these businesses shared facilities that survived the storm in a shift arrangement negotiated among them. Large increases in land values, particularly in areas that the gambling industry and other property developers desired, were raising an economic barrier against rebuilding commercial fishing infrastructure in their pre-storm locations.²⁴

By the end of 2006, total fish products processed had increased 2.6% to 129.3 million lbs from their 2004 lev-

²¹Notes from interviews conducted by Palma Ingles (bunnypevas@hotmail.com) for NMFS with fishermen and processors in Bayou La Batre, Ala., October 2005, and Grand Isle and Empire-Venice, La., 2006; see also IAI (footnote 2), p.118–122

²²Menhaden are a high volume, low value fish used to make products such as fish meal and fish oil.

²³Kieper, M. 2005. Blog. Katrina's Storm Surge (sixteen part series). Weather Underground (http://www.wunderground.com/education/Katrina_surge_contents.asp) accessed 23 Nov. 2013.

²⁴See footnote 2, p. 193–196, for a description of fishermen's, processors', and dealers' response and adaptation to Katrina's devastation through May/June 2006.



Figure 6.—Destroyed recreational boats and recreational boat storage facility, Biloxi, Miss., Oct., 2005. Photo: Palma Ingles.

el of 126 million lbs, while the value dropped from \$376 million to \$321 million. This reflected the shift of Louisiana catch to surviving Mississippi processors while Louisiana processors worked to restore their own processing capacity. For example, vessels from the Cameron, La., menhaden plant were assigned to the Moss Point, Miss., menhaden plant until the Cameron plant was reopened in mid-June 2006. The volume of fish processed in 2006 was 16% less than the 1998 figure of 154.7 million lbs, while the overall value of these products was 23% less in 2006 (\$321 million) than it was in 1998 (\$417 million).⁹

Alabama

Alabama's two coastal counties, containing 53 miles of coastline, are home to a substantial commercial fishing industry and an active recreational saltwater fishing industry with Bayou La Batre often referred to as Alabama's seafood capital. Major ship building businesses have been located in Mobile and Bayou La Batre for decades.

This area of the Gulf was furthest from the storm's center so the state's coastal areas were not as severely damaged as its neighbors further west. Nonetheless, commercial and recreational fishing infrastructure in some areas also sustained significant damage. Another factor affecting Alabama coastal areas was their incomplete recovery from Hurricane Ivan that had hit in September 2004, one year before Katrina. Many individuals and businesses had exhausted their financial resources in Ivan's aftermath and were not yet fully recovered (IAI²:232–233).

Immediately post storm, over 60% of the commercial docking and off-loading facilities were out of operation, and just over 47% of seafood processors and wholesale fish houses were either destroyed or too badly damaged to operate in Bayou La Batre, Coden, Mobile, and Bon Secour. Other types of infrastructure and support service losses ranged between 40% for net makers to 0% for seafood transport and trucking operations (Table 3). Many of the shrimp boats

in Bayou La Batre were lost or stranded in the marsh by Hurricane Katrina. Bayou waters rose as much as 16 feet during the storm, and 60% of the commercial shrimp boats in Bayou La Batre were destroyed (IAI²).

By May 2006, some commercial infrastructure had been restored or was otherwise operational and more services were available, e.g., more commercial docks and off-loading facilities were available, and the number of net makers and gear and related repair businesses had fully recovered and surpassed the number that existed in these areas prior to the storm possibly increasing to meet needs of less recovered areas to the west in Mississippi or even Louisiana. Nevertheless, the commercial fishing industry in Bayou La Batre faced an uncertain future.

Some Bayou La Batre offloading docks and processors had decided not to reopen. Labor for the processing plants continued in short supply. According to one processor, the continued lack of cold storage capacity since the storm remained a sig-

Table 3.—Alabama¹ fishing infrastructure damage 2004–06.²

Infrastructure or Service	Count			Loss	
	2004 Oct	2005 Oct	2006 May	% Loss Oct 2005 from 2004 baseline	% Loss May 2006 from pre-storm baseline
Boat yards/builders (commercial/recreational)	19	18	18	-5.3%	-5.3%
Commercial docking/off loading facilities	34	13	19	-61.8%	-44.1%
Net makers	5	3	6	-40.0%	20.0%
Fishing gear/electronics, welding/other repair	18	16	21	-11.1%	16.7%
Fish processors/wholesale fish houses	63	33	42	-47.6%	-33.3%
Seafood transport/trucking operations	8	8	8	0.0%	0.0%
Recreational docks/marinas/boat ramps	10	9	9	-10.0%	-10.0%
Bait & tackle/fishing supplies	6	5	6	-16.7%	0.0%
Seafood retail markets	28	26	27	-7.1%	-3.6%

¹Bayou La Batre, Coden, Mobile, Bon Secour. Post-Katrina 2005 and 2006 counts for category Boat Yards/Builders were not available for Bayou LaBatre/Coden and BonSecour for 2005 and 2006.

²Data source: Preliminary assessment of the impacts of Hurricane Katrina on Gulf of Mexico coastal fishing communities. DOC/NOAA/NMFS, Mar. 2007. (<http://sero.nmfs.noaa.gov/sf/socialsci/pdfs/FINAL-PUBLIC-N.pdf>).

nificant problem ramifying throughout the commercial sector of the industry (IAI²:218–221). Lack of funding and increased construction costs were constraining reconstruction of Bayou La Batre's commercial dock facilities (IAI²:225).

Finally, local industry participants commented that developers had their eyes on land that housed the city-owned marina for commercial fishing boats.²⁵ Mobile and Bon Secour seafood dealers and processors reported in May 2006 that they were trying to absorb product displaced from Bayou La Batre and areas as far west as Biloxi, Miss., but were having a difficult time doing so.

Seafood retailers were reporting that they had to source seafood products as far away as Texas because so few local fishermen in the northern GOM were fishing. Many local fishermen with smaller vessels found work clearing debris clogging the waterways, while others were waiting for fuel prices to drop and prices paid for their catch to increase before they would resume fishing (IAI²:233–236).

By the end of 2006, total pounds of seafood products processed had decreased 6% to 41.2 million lbs from their 2004 level of 43.9 million lbs, and the overall value of these products had declined 2% from \$131 million to \$128 million continuing a longer term trend. The overall value of pro-

cessed seafood products in 2006 (\$128 million) was 23% less than the 1998 value of \$167 million, and the total pounds processed in 2006 was 68% less than the 128.2 million lbs processed in 1998.⁹

Recreational charter boat operators incurred losses from trip cancellations up to several months following the storm according to one study (Chang et al., 2006). Many owner/operators were able to take their vessels out of harm's way before the storm, thus avoiding that kind of loss; however recreational marinas throughout the area had some damage requiring some to close for repairs. Loss of recreational docks and marinas to other forms of development had become a worry since Hurricane Ivan in September 2004 (IAI²:225, citing Chang et al., 2006).²⁶

2007 to 2012: More Disasters and New Emergencies

Following Hurricane Katrina, Hurricanes Ike and Gustav pummeled Alabama, Mississippi, and Louisiana in 2008. Both were declared major disasters by the Federal Emergency Management Agency (FEMA). Hurricane Isaac, also declared a major disaster, hit the area in 2012.

The center of Hurricane Gustav hit the Louisiana coast near Cocodrie, La., on 1 September 2008, and Ike arrived two weeks later on Galveston

Island, Tex., on 13 September. Both produced coastal tidal surges, torrential rains, and winds that affected the Louisiana, Mississippi, and Alabama coasts. Estimates vary: Ike is either the second (Blake et al., 2011:9) or third²⁷ costliest hurricane after Katrina. Estimated insurance losses to property for the two storms combined also vary, ranging between \$27.5 billion²⁸ and \$34.1 billion (Blake et al., 2011:9). Finally, in late August 2012, Hurricane Isaac lashed coastal Louisiana, Mississippi, and Alabama making landfall near the mouth of the Mississippi River. A state of emergency was again declared in all three states. Insured losses from Isaac are estimated at \$1 billion²⁹ to \$2.55 billion.³⁰

In 2011, a major flooding of the Mississippi River brought its own havoc. Drought followed by torrential rains in the Midwest and Southeast in 2011 disrupted a range of Mississippi River economic activities. To relieve pressure on the levee systems protecting Baton Rouge and New Orleans and their environs, the U.S. Army Corps of Engineers opened the Morganza Spillway for the first time in 38 years³¹; they also opened the Bonnet Carré Spillway.³² Vast quantities of fresh water emptied into the waters where Louisiana's and Mississippi's oysters live, damaging production.³³

²⁷Gussman, Phil: Sandy set to be 3rd costliest hurricane, but storms of the past offer perspective (<http://www.propertycasualty360.com/2013/03/22/sandy-set-to-be-3rd-costliest-hurricane-but-storms>) accessed 25 Nov. 2013.

²⁸<http://www.iii-insurancematters.org/insurance-and-disasters/facts/index.cfm>, accessed 25 Nov. 2013.

²⁹<http://www.eqecat.com/catwatch/hurricane-isaac-pounds-louisiana-2012-08-29/>, accessed 25 Nov. 2013.

³⁰Berg, Robbie, Presentation. National Hurricane Conference, New Orleans, La., 28 Mar. 2013. U.S. Dep. Comm., NOAA Natl. Weather Serv./Natl. Hurricane Cent. (<http://www.nhc.noaa.gov/outreach/presentations/Isaac2012.pdf>) accessed 23 Nov. 2013.

³¹<http://earthobservatory.nasa.gov/IOTD/view.php?id=50623>, accessed 25 Nov. 2013.

³²http://www.nola.com/weather/index.ssf/2011/05/bonnet_carre_spillway_opening.html, accessed 25 Nov. 2013.

³³"The Army Corp of Engineers (sic) report also said that the flood affected the estuarine system and the oyster industry in Mississippi Sound,

²⁵Notes from interviews conducted by Palma Ingles (bunnypevas@hotmail.com) for NMFS, with fishermen and processors in Bayou La Batre, Ala., October 2005.

²⁶Walker et al. (2006) provides additional information on recreational fishing industry losses and post storm prospects based on a National Association of Charterboat Operator's study.

The spillways were closed by the end of June 2011.

The Great Recession

The official dates for the worst U.S. recession in more than 75 years are December 2007 through June 2009³⁴, the recession has been followed by a sluggish recovery. The recession increased state poverty rates in a region that already had generally high poverty rates (Gabe, 2013). According to one recent report, the recession also caused “... the largest collapse in state revenues on record” and as of the first quarter of 2012, they remained 5.5% below their prerecession levels (Olliff et al., 2012). Unemployment also increased dramatically, spreading broadly through several sectors of the economy, effectively eliminating all the jobs gained in the previous expansion (Goodman and Mance, 2011). The local economies of the coastal areas of Mississippi, Louisiana, and Alabama were all significantly affected while struggling to overcome widespread property damage and loss from previous and recent hurricanes.

Deepwater Horizon Oil Spill

Just as the northern GOM fishing industry was beginning to show some recovery from Hurricanes Gustav and Ike and the recession, the largest accidental marine oil spill to occur to date in the United States began on 20 April 2010 in the GOM. The Deepwater Horizon drilling platform, located about 41 miles off the Louisiana coast, exploded, killing 11 people and discharging over 210 million gallons of oil before the well was capped 87 days later (NOAA, 2013). The spill extensively damaged marine and wildlife habitat, impacting the fishing and tourism industries in the northern Gulf. Chemical dispersants were used on a massive scale to try to control the oil.

Lake Borgne, and Breton Sound, La. Economic losses to the oyster industry in Mississippi alone in 2011 were approximately \$60 million, according to the report.” Cited in A. Sainz (2013).
³⁴Business Cycle Dating Committee, U.S. Business Cycle Expansions and Contractions National Bureau of Economic Research (<http://www.nber.org/cycles.html>) accessed 4 Dec. 2013.

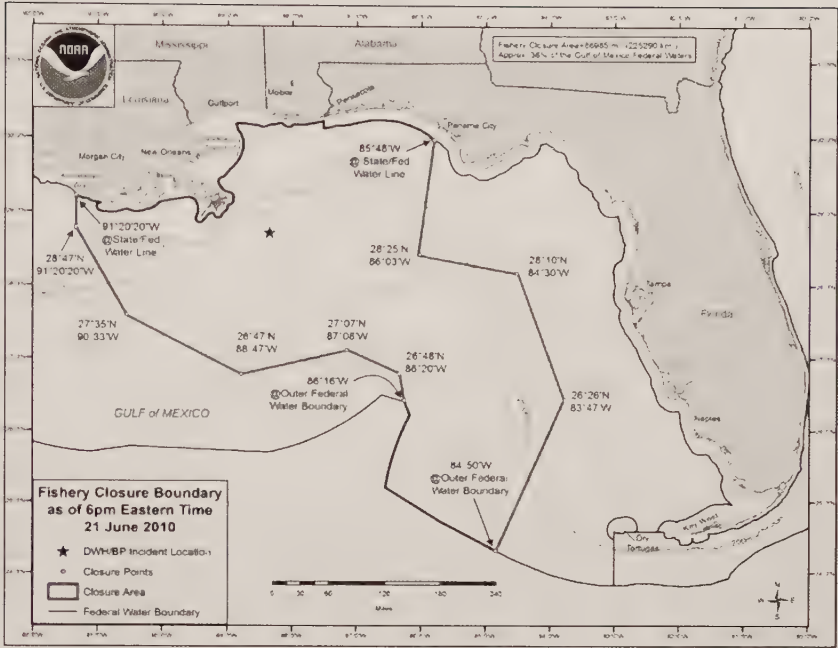


Figure 7.—Gulf of Mexico fishery boundary closure 21 June 2010. Source: NMFS/NOAA.

The affects of the dispersants on marine life when used in such large quantities remain a concern (Silliman et al., 2012). In July 2013, BP estimated its bill to date for cleanup and compensation was in excess of \$42.4 billion dollars (Gosden, 2013).

Following the explosion, more than 80,000 mi² of commercial and recreational fishing grounds were closed (Fig. 7) because of concern about the safety for human consumption of the seafood harvested in the area of the spreading spill³⁵, and the Federal Government began a large program sampling and testing GOM waters and seafood for contaminants (Ylitalo et al., 2012). This resulted in many fishermen and seafood processors being temporarily put out of business, some permanently. Joseph Jewell, Administrator for the Mississippi Department of Marine Resources, summarized oil spill impacts on Mississippi shrimpers this way:

³⁵See NOAA Deepwater Horizon Archive for historical data on seafood safety and fisheries closures at <http://www.noaa.gov/deepwaterhorizon/>, accessed 10 Dec. 2013.

“And then as you know, all of the state waters were closed for a short period of time, just under two months, and that may seem small to most people, but that period of time was right during the height and the most productive part of the shrimping season. That’s when most of the shrimp are typically in the Mississippi Sound. That’s when most of the shrimpers make their most profits, their largest catches, and they were unable to get out and shrimp during that time.”³⁶

³⁶Joseph Jewell, Administrator, Mississippi Department of Marine Resources, Interview 10/12/11, NOAA’s Deepwater Horizon Oil Disaster Oral History Project (<http://www.st.nmfs.noaa.gov/voicesfromthefisheries/dwh/JJewell.html>) accessed 12 Dec. 2013. Social Impact and Resiliency in the Wake of the Deepwater Horizon Industrial-Environmental Disaster: Development of Well-being Indicators and Collection of Oral Histories: Component Two -Oral Histories. Susan Abbott-Jamieson, National Marine Fisheries Service, Principal Investigator and Louis M. Kyriakoudes, Center for Oral History and Cultural Heritage, The University of Southern Mississippi, Co-Principal Investigator. Funded by a grant from National Marine Fisheries Service, National Oceanographic and Atmospheric Administration through the Northern Gulf Institute. Interviews conducted along the North-

One owner of an Alabama seafood processing plant reported a steep drop in his company's production:

"Well, actually for 2010 our production was off somewhere around 80%, and so it was pretty devastating. We lost quite a few customers because we couldn't supply them, and it's not the easiest thing in the world to get a customer back after you've lost them because they feel that, 'These other people helped me when you couldn't.' And it's hard to get them back."³⁷

Some fishermen found short-term work for BP helping to clean up the oil spill; others did not. Because many fishermen operate on a cash basis, their inability to document their actual earnings meant many were not compensated for their true losses. Navigating the claims process was also difficult, particularly for the Vietnamese fishermen who did not have the paperwork and negotiation skills or the skills to deal with the claims process hierarchy.^{38,39} First-person accounts reflecting a variety of experiences in the aftermath of the oil spill are included in the Deepwater Horizon Oil Disaster Oral History Project Collection that can be

accessed on NOAA's Voices from the Fisheries Project website.⁴⁰

After the Gulf was fully reopened to fishing, sales of Gulf seafood continued to decline. Consumer's beliefs that seafood coming from the Gulf might not be safe were fueled by continuing reports of new discoveries of more oil columns and oil mats along the affected Louisiana, Mississippi, Alabama, and Florida coasts.⁴¹ A growing literature is available examining the health of oil spill workers and residents living in the affected areas (Diaz, 2011; Goldstein et al., 2011; Levy and Nassett, 2011; Osofsky et al., 2011). According to some studies, it could take decades for the deep sea to recover from the oil spill (Finn, 2013).⁴²

The BP oil spill added yet another set of challenges for both the commercial and recreational fishing sectors that were already struggling to rebound from a general decline in marine resources, a series of hurricanes that devastated the Gulf, and a long and deep recession.

The Impacts

Unable to return to the original set of Katrina-damaged fishing communities to repeat the survey that was done in 2005–06 by IAI, the authors identified three indicators with available data to help them understand how these disasters have impacted fishing communities and aspects of the fishing industry. These indicators are 1) population change between 2000 and 2010 as reported by the U.S. Census Bureau in the communities surveyed

Table 4.—Total Fishing community population change by state 2000–10.^{1,2}

State	2000	2010	N Difference	% Loss
Alabama	204,349	201,926	2,423	-11.5%
Mississippi	168,161	156,433	11,728	-7.0%
Louisiana	46,192	23,586	22,606	-51.1%
Total	418,702	381,945	36,757	-8.8%

¹Limited to communities surveyed as part of "Preliminary assessment of the impacts of Hurricane Katrina on Gulf of Mexico coastal fishing communities," Final Technical Report prepared for NMFS, by Impact Assessment, Inc., 2007 (<http://sero.nmfs.noaa.gov/st/socialsci/pdfs/FINAL-PUBLIC-N.pdf>).

²Data source: U.S. Census SF 1 Tables (<http://www.census.gov/census2000/sumfile1.html>) accessed 17 Feb. 2014; (<http://factfinder2.census.gov/faces/nav/jsf/pages/index.xhtml>) accessed 17 Feb. 2014.

in 2005–06, and for the states of Alabama, Mississippi, and Louisiana for 2003–12; 2) changes in the number of processing and wholesale plants, and the number of employees in those plants; and 3) changes in pounds landed and their value as reported in annual NMFS fisheries statistics reports (NMFS, 2003–2013). Although we cannot claim the events we described in the previous section have caused the changes we next describe, we can point out patterns of association they have with these events.

For the fishing communities surveyed in Alabama, Mississippi, and Louisiana after Hurricane Katrina, overall population declined 8.8% during the 10-year period between 2000 and 2010 (Table 4). The states differ among themselves, however, ranging from a low of 1.2% in Alabama to a high of 51.1% in Louisiana. Four communities were surveyed in Alabama; losses occurred only in Coden (15.6%), while the other three communities gained population, two substantially—Bon Secour (74.4%) and Bayou La Batre (10.6%). Bayou La Batre is home to several processors who handle domestic and imported seafood.

Of Mississippi's seven surveyed communities, five lost population and two gained. The average loss was 22.3%. The heaviest loss was in the adjacent Long Beach (14.6 %)/Pass Christian (29.9%) area. D'Iberville gained 24.7% and Bay St. Louis gained 12.8%. D'Iberville is adjacent to Biloxi—the center of the area's gaming industry.

ern Gulf Coast, 2011–2012. Original interviews are housed at the Center for Oral History and Cultural Heritage, The University of Southern Mississippi (<http://www.usm.edu/oral-history>) accessed 10 Feb. 2014. The interviews can be accessed by the public through NOAA's Voices from the Fisheries website (<http://www.st.nmfs.noaa.gov/voicesfromthefisheries/>) accessed 10 Feb. 2014. They constitute the Deepwater Horizon Oil Disaster Oral History Collection.

³⁷Ladnier, Greg. Owner, Sea Pearl Seafood Processing Plant, Bayou La Batre, Ala. NOAA's Deepwater Horizon Oil Disaster Oral History Project, Interviewed 25 Jan. 2012 (<http://www.st.nmfs.noaa.gov/voicesfromthefisheries/gregladnier.html>) accessed 2 Dec. 2013. See footnote 36.

³⁸Vietnamese interviews, NOAA's Deepwater Horizon Oil Disaster Oral History Project (<https://www.st.nmfs.noaa.gov/voicesfromthefisheries/dwhimpactvietnam.html>) accessed 5 Dec. 2013. See footnote 42.

³⁹Abbott-Jamieson, S. 2013. Gulf of Mexico Working Waterfronts and Ethnic Patterns of Disaster Vulnerability and Resilience. Presentation. National Working Waterfronts and Waterways Symposium, March 25–28, Tacoma, Wash. (http://wsg.washington.edu/mas/pdfs/nwnews/B4/B4_Abbot_Jamieson.pdf) accessed 5 Dec. 2013.

⁴⁰The Deepwater Horizon Oil Spill Oral History Collection is available online at <http://www.st.nmfs.noaa.gov/voicesfromthefisheries/>, accessed 3 Dec. 2013. Original interviews are housed at the Center for Oral History and Cultural Heritage, The University of Southern Mississippi (<http://www.usm.edu/oral-history>) accessed 5 Dec. 2013.

⁴¹See NOAA Deepwater Horizon archive for historical data on oil columns and related information (<http://www.noaa.gov/deepwaterhorizon/>) accessed 10 Dec. 2013.

⁴²The NOAA Central Library hosts a publically accessible compilation of bibliographic resources on the DWH oil spill; new references are added continuously (<http://www.lib.noaa.gov/researchtools/subjectguides/dwh.html>) accessed 10 Dec. 2013.

Table 5.—Processors, wholesalers, and employment 2003–12: Alabama, Mississippi, Louisiana combined.¹ Light gray background = high value. Dark gray background = low value.

Year	Processing		Wholesale		Total		Significant Events ^{2, 3}
	Plants	Employment	Plants	Employment	Plants	Employment	
2003	194	6077	171	1283	365	7360	
2004	171	6200	188	1257	359	7458	Hurricane Ivan
2005	148	7450	178	1041	326	8491	Hurricanes Dennis, Katrina, Rita
2006	141	6970	162	807	303	7777	
2007	134	6692	149	851	283	7543	Recession officially begins Dec 2007
2008	134	6330	143	823	277	7153	Recession continues; Hurricanes Gustav and Ike
2009	129	6557	140	797	269	7384	Recession officially ends June 2009
2010	125	6104	142	741	267	6845	DWH oil spill closures
2011	118	5614	140	950	258	7496	Mississippi River floods
2012	116	5450	138	1015	254	6465	Hurricane Isaac

¹Processor and wholesaler data 2003–10 from Fisheries of the U.S. online editions for each year. (<http://www.st.nmfs.noaa.gov/commercial-fisheries/fus/index>) accessed 11 Jul. 2013. Years 2011 and 2012 from Bureau of Labor Statistics, 2012 preliminary data (<http://data.bls.gov/cgi-bin/srgate>) accessed 18 Jul. 2013

²Major disaster data from FEMA tables for individual states. Only those that were declared major disasters are included (<http://www.fema.gov/disasters>) accessed 11 Jul. 2013.

³Recession dates from the National Bureau of Economic Research (<http://www.nber.org/cycles/sept2010.html>) accessed 11 Jul. 2013.

All eight surveyed communities or community complexes in Louisiana lost population with Grand Isle losing the least (15.9%), and Delacroix the most (72.6%). The others ranged between 43.5% and 65.4% with an average population loss of just under 44%. Population loss in Louisiana's surveyed fishing communities has been dramatic. Louisiana's fishing communities are heavily involved in shrimping.

Communities that have suffered the most damage tend to have been the slowest to recover. Lack of adequate insurance in the first instance, and an inability to afford dramatically more expensive insurance after hurricane damage, have meant that many have not attempted to rebuild in their home communities. Destruction of large areas that included working waterfronts servicing commercial fisheries has also included the loss of moderately priced housing for people working in the fishing industries. This has cleared the way for increased gentrification in areas adjacent to newly expanding gaming industry facilities, particularly in the Biloxi-D'Iberville, Miss., area. Competition among casinos and other developers for desirable waterfront and near-shore property in both Biloxi's Back Bay area as well as in nearby D'Iberville has significantly increased property values and raised taxes. This has led many of the area's commercial and recreational fishing industry businesses to move to new locations,

often inland. This is paired with the development of higher value housing for those who want to be near the water and have sufficient means to purchase it. At the same time, the recreational fishing industry has been provided new opportunities from expanding tourism tied to the casinos in Mississippi, as well as new residents with means and an interest in recreational and sport fishing. These patterns have been noted by others (Pettersen et al., 2006).

Information on the number of processing and wholesale plants, and employees in those plants is found in Table 5. Between 2003 and 2012, the overall trend is for a decline in both the number of processing and wholesale plants, and an associated decline in the number of employees. The three states together lost 30.4% (N=111) of their processing and wholesale plants combined during this period.

Losses have been greater for processing plants however than for wholesale plants. There were 40.2% (N=78) fewer processing plants in 2012 than there were in 2003, and 26.6% (N=50) fewer wholesale plants. The peak year for employment overall was 2005, and the lowest employment overall is reported in 2012. There were 2,026 fewer employees for a loss of 23.9%.

Turning now to examine the relationship between the major natural and man-made disasters and plant closures during a period of steady decline overall, the largest year-on-year losses occurred between 2004 and 2007 when

76 plants of all kinds closed. During this period there were four major and devastating hurricanes that impacted the area. The number of plant closings is testament to the cumulative damage to fisheries infrastructure.

Between 2008 and 2009, another 14 plants closed. This period saw two more damaging hurricanes and the economic trough of the Great Recession. Another nine plants closed during 2010–11, when the Deepwater Horizon oil spill resulted in major fisheries closures in the GOM, and though the recession was officially over, the economy remained sluggish. There is some evidence that the DWH oil spill may have contributed to a dip in processing and wholesale plant jobs (539 fewer employees reported for 2010), but those jobs were recovered during 2011, only to be lost again in 2012 with the continued decline in number of plants. Four more plants closed in 2012 when Hurricane Isaac, the seventh since 2003, hit the area.

The amount of seafood landed in the GOM has ebbed and flowed over the 2003–12 period shown in Table 6.⁴³ Shrimp and menhaden are the two primary species harvested in northern GOM federally managed waters and the amount harvested of each of these varies year by year. The table shows that the pounds of seafood landed were the lowest in Louisiana in 2005, the year Hurricane Katrina and

⁴³Table 6 does not include landings of finfish and shellfish harvested in state waters.

Table 6.—Pounds landed, value, and significant events 2003–12: Alabama, Mississippi, Louisiana Combined.¹ Light gray background = high value. Dark gray background = low value.

Year	Alabama		Mississippi		Louisiana		Significant Events ^{2,3}
	Pounds	Value	Pounds	Value	Pounds	Value	
2003	25,344	39,521	213,116	45,508	1,189,448	294,011	
2004	26,559	37,036	183,762	43,791	1,096,590	275,014	Hurricane Ivan
2005	23,614	39,209	167,646	23,451	847,172	253,037	Hurricanes Dennis, Katrina, Rita
2006	34,151	49,185	221,832	21,741	899,428	255,269	
2007	29,322	48,333	228,137	39,983	951,240	259,564	Recession officially begins Dec 2007
2008	24,534	44,234	201,822	43,697	915,956	272,857	Recession continues; Hurricanes Gustav and Ike
2009	27,633	36,961	230,284	37,998	1,000,815	280,691	Recession officially ends June 2009
2010	14,408	27,140	111,242	21,913	1,004,774	247,948	DWH oil spill closures
2011	26,041	50,764	278,056	30,207	1,515,571	339,296	Mississippi River floods
2012	24,677	43,065	263,678	49,276	1,214,194	327,952	Hurricane Isaac

¹Landings and value data 2003–2010 from Fisheries of the U.S. online editions for each year (<http://www.st.nmfs.noaa.gov/commercial-fisheries/fus/index>) accessed 11 Jul. 2013.

²Major disaster data from FEMA tables for individual states. Only those that were declared major disasters are included (<http://www.fema.gov/disasters>) accessed 11 Jul. 2013.

³Recession dates from the National Bureau of Economic Research (<http://www.nber.org/cycles/sept2010.html>) accessed 11 Jul. 2013.

two other hurricanes hit.⁴⁴ Mississippi landings were also impacted that year; Alabama's less so. In 2008, the recession hit its trough and two more major hurricanes hit the area. The drop in landings from 2007 to 2008 was 16.4% for Alabama, 11.5% for Mississippi, and 3.7% for Louisiana.⁴⁵ During 2009, landings bounced back in all three states. The official end of the recession was in June of that year, and there were no major hurricanes.

The lowest weight by pounds landed for Alabama and Mississippi was in 2010, the year of the DWH oil spill, which was also the year for the lowest landings by value for Louisiana. Alabama reported a 47.9% drop in landings compared to the previous year, while Mississippi's landings dropped 26.6%. Louisiana's landings held steady, but dropped in value. Excluding other species for the years 2009–12, the quantity of shrimp and menhaden landed was the lowest in 2010 (NMFS, 2011). This suggests that both of these fisheries were impacted in 2010 by the DWH oil spill's extensive closures and the public's fear of possible contamination of Gulf

seafood and resultant refusal of consumers to buy it. The Mississippi River floods of 2011 impacted Mississippi and Louisiana oyster beds in inshore waters but did not impact federally managed fisheries so those losses are not reflected in these data.

With the enforced closures ended, 2011 produced the highest weight by pounds landed since 2003 in Mississippi and Louisiana, followed in 2012 by the second highest landings by pounds for these states. The highest value for pounds landed also occurs in 2011 for Louisiana and Alabama, and in 2012 for Mississippi. These data suggest stability in these marine resources for the 2003–2012 period, coupled with a remarkable ability of the remaining commercial fishermen to capture those resources despite the sometimes horrific damage to their homes, their fishing communities, and the infrastructure they require to support their fishing effort.⁴⁶

Summary and Conclusions

In the past decade, GOM commercial and recreational fishermen and others in the fishing industry have faced many obstacles to continuing in business. The unfolding nemesis we have attempted to describe combines natural and manmade events, in an ongoing process with no satisfactory end in sight for traditional fishing communities.

⁴⁶The literature review included in VanderKooy (2012), p. 10–10–12 provides a good discussion of factors affecting Gulf fishing communities.

Although the area as a whole has lost population, some fishing communities have lost significantly more, particularly in Louisiana, while some have gained in Mississippi and Alabama. Mississippi's gains appear to be related to the expansion of the gaming industry in areas previously devoted to fishing support, while Alabama's gains are located in processing centers such as Bayou La Batre.

There has been an overall decline in both numbers of processors, wholesalers, and their employees during the period examined; the 2004–07 period coinciding with repeated hurricanes shows the sharpest declines. Pounds of fish landed, while impacted by hurricanes and the DWH oil spill, rebounded by 2011–12 to their highest level since 2003; their highest value occurs in 2011–12 as well. The fishing industry in these states as measured by pounds and value of landings has shown an ability to recover from the shock of hurricane damage and oil spill closures over the past decade, but the longer-term economic downward trends as measured by numbers of processors, wholesalers, and their employees continues.

Other factors we have not discussed include increasing operating costs and the increasing age of commercial fishermen; changes in marine fisheries management regimes; relative health of the fish and shellfish stocks; price competition from imported farmed seafood; environmental degradation from agricultural runoff in the Mississippi River drainage and associated al-

⁴⁴Analysis of the relationship between loss of infrastructure in hurricane-damaged communities and subsequent pounds landed would be valuable. This should include both state and federal marine fisheries. We do not have the data to do this analysis.

⁴⁵See Gulf States Marine Fisheries Commission Report (Miller and Isaacs, 2011) for an analysis of the economic condition of Gulf of Mexico state waters shrimping fleet's economic condition based on data collected in 2008. Their findings are similar to those reported for the federally permitted shrimpers.

gal blooms; loss of wetlands from new coastal development; future effects of regional oil and gas drilling and refining; and future effects of climate change and population growth. There are productive subjects here for future research.

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Stakeholder Attitudes Toward Ecosystem-based Fisheries Management

AYEISHA A. BRINSON and KRISTY WALLMO

"Ecosystem management integrates scientific knowledge of ecological relationships within a complex sociopolitical and values framework toward the general goal of protecting native ecosystem integrity over the long term" (Grumbine, 1994:31).

"Ecosystem management is management that is adaptive, is specified geographically, takes into account ecosystem knowledge and uncertainties, considers multiple external influences, and strives to balance diverse social objectives" (NOAA¹).

An Ecosystem Approach to Management

Ecosystem management is widely acknowledged as a holistic approach to natural resource management—an approach that considers interactions between physical, biological, and human components of an ecosystem and promotes ecosystem health and long-term sustainability (Mace, 2004;

Pikitch et al., 2004; U.S. Commission on Ocean Policy, 2004; Agardy, 2005; Tudela and Short, 2005; Murawski, 2007). Currently, the approach is a popular prescription to remedy stress and deterioration in marine ecosystems, and it is frequently referenced as necessary in the evolution of marine fisheries management (Brodziak and Link, 2002; Hilborn et al., 2004; Pikitch et al., 2004).

Although an ecosystem approach to fisheries management has received increasing attention during the last decade, ecosystem management itself is far from novel. In 1970, policy analyst Lyndon Caldwell suggested using ecosystems as a basis for land management, noting that such a shift would require a reconfiguration of the conventional (political) system (Grumbine, 1994). Though an immediate shift did not ensue, by the late 1980's an ecosystem approach to land management was supported by many scientists and managers (Grumbine, 1994) and by the mid-1990's ecosystem activities (focused primarily on managing terrestrial or freshwater ecosystems) were underway in 18 federal agencies and many state agencies and private firms (Morrissey et al., 1994).

Ubiquitous calls for an ecosystem approach for managing marine resources followed (EPAP, 1999; Pikitch et al., 2004) many of which advocated that humans are part of the ecosystem—a relatively novel concept for fisheries management—and thus relationships between human and non-human elements must be accounted for in a management paradigm (Busch et al.²). Though localized examples of ecosystem approaches to fisheries management may have existed prior to 1995, the United Nations Food and Agriculture Organization's Code of Conduct for Responsible Fisheries (FAO, 1995) marked an important step in establishing a framework for ecosystem considerations in fisheries management. This framework, in part, promoted the establishment of principles for responsible fishing and fisheries conservation, the protection of living aquatic resources and their environments, and research on fisheries and their associated ecosystems (FAO, 1995).

In the ensuing years, much literature was published on almost every aspect of an ecosystem approach to fisheries management (EAFM), including what it is and how it should or could be implemented (Link, 2002; Francis

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ABSTRACT—NOAA's National Marine Fisheries Service (NMFS) conducted a survey of fisheries stakeholders on the Gulf and East Coasts of the United States to learn their views on ecosystem-based fisheries management (EBFM) of fisheries resources. The survey asked a series of attitude and opinion questions along with general environmental literacy and demographic questions to a sample of 7,850 fisheries stakeholders, stratified by region. Results indicate that respondents' knowledge of the status of fisheries resources is qualitatively similar to NMFS ratings, though generally respondents were less than satisfied with current fisheries management. Results also suggest that, despite concerns over several specific measures, respondents generally see potential in an EBFM approach to management.

¹NOAA. 2004. New priorities for the 21st century. National Marine Fisheries Service Strategic Plan updated for FY 2005–FY 2010. U.S. Dep. Commer., NOAA, 19 p. (avail. from the NOAA Central Library and online at: <http://www.nmfs.noaa.gov/mb/strategic/NMFSstrategicplan200510.pdf>).

²Busch, W.-D. N., B. L. Brown, and G. F. Mayer (Editors). 2003. Strategic guidance for implementing an ecosystem-based approach to fisheries management. U.S. Dep. Commer., NOAA, NMFS, Silver Spring, MD, 62 p. Avail. online at http://www.nmfs.noaa.gov/ocs/mafac/meetings/2003_05/mafac_rev_5th_7Finalwref.pdf.

et al., 2007; Sanchirico³). Although no universal definition of EAFM exists, many scientists agree that monitoring and adaptive management, ecological integrity, ecological boundaries, accounting for uncertainty, balancing diverse societal needs, and the consideration of future generations are important principles that EAFM should address (Brodziak and Link, 2002; Sissenwine and Murawski, 2004; Garcia and Cochrane, 2005; EPAP, 1999).

Today many agencies charged with managing marine systems are adopting an ecosystem approach or are incorporating key principles of the approach. NOAA's National Marine Fisheries Service (NMFS) is among those agencies moving toward EAFM, stating its goal to "protect, restore, and manage the use of coastal and ocean resources through an ecosystem approach to management" in its strategic plan (NMFS, 2007). Though U.S. fisheries management has traditionally focused on management of a single species or species complex, the adoption of EAFM is not an about-face in management style; rather, it is a move along the continuum of the management spectrum bounded by single-species management at one end and ecosystem management at the other.

NOAA defines an ecosystem approach to management as one that is "adaptive, geographically specified, takes into account ecosystem knowledge and uncertainties, considers multiple external influences, and strives to balance diverse societal objectives" (NOAA¹). And while defining an ecosystem approach is no easy task, implementing the approach may be even more challenging. The following quotes (cited in Bengston et al., 2001) illustrate sentiments toward terrestrial ecosystem management, and there is no evidence that implementing ecosystem management for marine systems will be easier.

"Personally, I think that ecosystem management is an appropriate management policy, but the way it has been implemented has unnecessarily interrupted nearly a century of progressive forest management." (MacWilliams, 1997).

"Many fishery and wildlife managers now accept the whole-ecosystem view in principle, but practicing it is a different matter." (Radin, 1997).

In 2007 Francis et al. offered ten action items which they suggest will help bridge the gap between general principles of EAFM and specific methodologies (Francis et al., 2007). With one exception these action items address only the natural sciences; however, difficulties in implementation often arise over competing management objectives and the preferences of different stakeholder groups.⁴ This underscores the importance of understanding what it is that stakeholders desire from an ecosystem approach to management, and what types of objectives are preferred by which stakeholders. Social science research can help managers understand the diversity of stakeholder preferences concerning EAFM. Prior research has shown predominantly favorable attitudes toward ecosystem management in the context of terrestrial ecosystems (Steel et al., 1994; Manning et al., 1999; Bengston et al., 2001), though less is known about fisheries stakeholders' attitudes, opinions, and concerns about an ecosystem approach to managing fisheries.

In 2010, President Obama signed Executive Order 13547 establishing the National Ocean Policy, with one of the primary objectives to adopt an ecosystem-approach to managing the nation's coasts and oceans.⁵ While there are limited formal assessments of what fisheries stakeholders think of current management, such an assessment

could help managers focus on specific areas or objectives that may need attention when developing guidelines and implementing EAFM.

Surveying Stakeholder Opinions

To understand what fisheries stakeholders think about both current and ecosystem-based management, the NMFS conducted a mail questionnaire of fisheries stakeholders beginning in April 2006 (see Appendix). A sampling frame of stakeholders was developed through coordination with the New England, Mid-Atlantic, South Atlantic, and Gulf of Mexico Fishery Management Councils and relied primarily on mailing lists maintained by the Councils' and NMFS Office of Constituent Services. The frame ($n=18,000$) consisted of six primary types of stakeholders: aquaculture (4% of frame); seafood importer/exporter/wholesaler (10%); commercial fishermen (36%); academic and non-NOAA scientific (16%); non-governmental organizations (3%); other (31%). The "other" category consisted largely of private citizens who had previously expressed an interest in marine management by attending a Fishery Management Council (FMC) meeting or writing or phoning an FMC, the Atlantic States Marine Fisheries Commission, or NOAA.

Four regional-specific survey versions were developed for New England (Connecticut, Rhode Island, Massachusetts, New Hampshire, and Maine), the Mid-Atlantic (North Carolina, Virginia, Maryland, Delaware, Pennsylvania, New Jersey, and New York), the South Atlantic (North Carolina, South Carolina, Georgia, and the east coast of Florida down to Key West), and the Gulf of Mexico (west coast of Florida, Alabama, Mississippi, Louisiana, and Texas). Surveys were developed with collaboration with each region's FMC. Each survey contained five sections: Section A gauged respondents participation in and awareness of fisheries management; Section B assessed respondents opinions of current fisheries management for regionally specific fish and protected species stocks;

³Sanchirico, J. N., M. D. Smith, and D. W. Lipton. 2006. An approach to ecosystem based fishery management. Resources for the Future Discussion Paper, RFF DP 06-40, Wash. D.C., 30 p. (Avail. online at: <https://www.rff.org/files/sharepoint/WorkImages/Download/RFF-DP-06-40.pdf>).

⁴For purposes of this paper, we define stakeholder as those interested and involved in the fishery management process, more specifically the federal Fishery Management Councils.

⁵More information on the National Ocean Policy Implementation Plan may be found online at <http://www.whitehouse.gov/administration/eop/oceans/policy> (accessed 2 Apr. 2014).

Table 1.—Mail returns by disposition.

Disposition	No. returned surveys
Initial surveys mailed	7,850
Refused	42
Undeliverable ¹	1,379
Completed Surveys	2,296
Final Response rate	35%

¹Undeliverable includes those surveys that were non-deliverable (incorrect address) or the respondent was deceased.

Section C examined respondents preferences for the types of goals and objectives that should be pursued within a fisheries management framework and asked them about their satisfaction with current management; Section D asked respondents about their expectations related to ecosystem based management; and Section E collected demographic data. Section B was the only section of the survey that varied by region. The survey instrument was tested with two focus groups in Delaware and two focus groups in Florida and refined based on focus group feedback.

Survey administration followed a modified Dillman Design (Dillman, 2007). Each respondent was mailed a pre-notification letter which explained the survey, described how the data would be used, and encouraged cooperation. Within five days, a survey instrument with a cover letter was sent to each respondent. One week after this mailing, a postcard was mailed to all respondents thanking those who had completed the survey, and encouraging those who had not completed it to do so. Finally, two weeks after the initial mailing, a second survey instrument was sent to all non-respondents, with a modified cover letter. A customized tracking database system was used to log mail returns and track survey progress. Initially, 7,850 surveys were sent in the first mailing. By the end of the mailings, 2,296 surveys were returned for a response rate of 35% (Table 1).

Following administration of the survey, a non-response bias check was completed. Thirty-seven percent of the undeliverable records were matched with a telephone record. In addition to a few demographic questions, selected

content questions from the mail survey were included in the telephone non-response questionnaire. Mail respondents tended to report higher education levels, higher incomes, and were more likely to include female respondents.

Percentage responses are reported for the survey questions. The results present the percentages of those responding to a question. No further statistical analysis was completed; therefore there are no standard errors or goodness of fit estimates to present.

**Stakeholder Opinions:
The Good, the Bad,
and the Unsure**

The Good

Respondents were asked about their opinion of the status and management of selected fish stocks (or stock complexes) that occur in their region of residence (Table 2). Respondents were

asked whether they believed a stock was stable, overfished but recovering, or overfished and not recovering, and also asked to rate the current management of selected stocks using a scale of excellent, good, fair, or poor. The response “I am unsure” was also available for both status and management questions. Stakeholder ratings of the status of fish stocks were compared to the NMFS Fish Stock Sustainability Index (FSSI), an index used by NMFS to measure the sustainability of over 230 separate stocks. The FSSI is calculated by assigning a score for each stock based on five criteria: 1) whether the stock status is known, 2) whether the stock is overfished, 3) whether the stock is subject to overfishing, 4) whether the stock biomass is above the point defined as overfished, and 5) whether the stock biomass is 80% or more of the biomass required to produce maximum sustainable yield. The

Table 2.—Fish stocks rated by stakeholders in the four surveyed regions.

North Atlantic	Mid-Atlantic	South Atlantic	Gulf of Mexico
Atlantic sea scallop, <i>Plactoptecten magellanicus</i>	Summer flounder, <i>Paralichthys dentatus</i>	Mahi mahi, <i>Coryphaena hippurus</i>	Red drum, <i>Sciaenops ocellatus</i>
Groundfish ¹	Black sea bass, <i>Centropomus striata</i>	Spiny lobster, <i>Panulirus argus</i>	Spiny lobster, <i>Panulirus argus</i>
Whiting/red hake ²	Bluefish, <i>Pomatomus saltatrix</i>	Snapper/grouper ⁴	Snapper/grouper ⁶
Goosefish (monkfish), <i>Lophius americanus</i>	Golden tilefish, <i>Lopholatilus chamaeleonticeps</i>	Mackerel, <i>Scomberomorus cavalla</i> and <i>S. maculatus</i>	Mackerel, <i>Scomberomorus cavalla</i> and <i>S. maculatus</i>
Red crab, <i>Chaceon quinquequens</i>	Atlantic mackerel, <i>Scomber scombrus</i>	Shrimp ⁵	Shrimp ⁷
Atlantic herring, <i>Clupea harengus</i>	Squid, <i>Loligo pealeii</i> and <i>Illex illecebrosus</i>		
Atlantic salmon, <i>Salmo salar</i>	Butterfish, <i>Peprilus triacanthus</i>		
Skates ³	Atlantic surfclam, <i>Spisula solidissima</i>		
	Ocean quahog, <i>Arctica islandica</i>		
	Spiny dogfish, <i>Squalus acanthias</i>		
	Scup, <i>Stenotomus chrysops</i>		

¹Groundfish refers to a complex of 15 species, for more information, visit, <http://www.nero.noaa.gov/nero/fishermen/images/Multispecies/index.html>, accessed 2 Apr. 2014.

²Whiting/red hake refer to silver hake, *Merluccius bilinearis*; offshore hake, *M. albidus*; red hake, *Urophycis chuss*.

³Skates refer to the Northeast skate complex, which comprises seven species. For more information, visit, <http://www.nero.noaa.gov/nero/fishermen/images/skates/>, accessed 2 Apr. 2014.

⁴Snapper/grouper refers to 14 species of snappers and 20 species of groupers in the South Atlantic snapper/grouper complex managed by the South Atlantic Council, for more information, visit http://safmc.net/sites/default/files/SAFMC_ManagedSpecies_12182012.pdf, accessed 2 Apr. 2014.

⁵Shrimp refers to rock shrimp and three species of penaeid shrimp managed by the South Atlantic Council, for more information, visit <http://safmc.net/fish-id-and-regs/regulations-species#Species%20Regs>, accessed 2 Apr. 2014.

⁶Snapper/grouper refers to 11 species of snappers and 11 species of groupers in the Gulf reef fish complex managed by the Gulf Council, for more information, visit <http://www.gulfcouncil.org/Beta/GMFMCWeb/downloads/species%20managed.pdf>, accessed 2 Apr. 2014.

⁷Shrimp refers to four species of shrimp managed by the Gulf Council, for more information, visit <http://www.gulfcouncil.org/Beta/GMFMCWeb/downloads/species%20managed.pdf>, accessed 2 Apr. 2014.

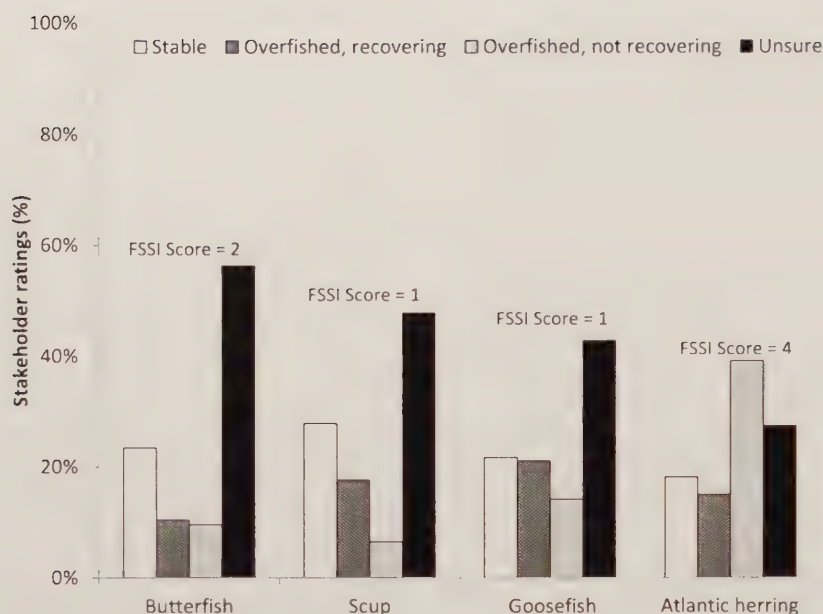


Figure 1.—Stakeholder ratings of the status of the four stocks for which their ratings were inconsistent with FSSI scores.

maximum FSSI score a stock can receive is four, denoting the highest level of sustainability. The lowest sustainability score a stock can receive is zero.⁶

In the Gulf of Mexico and South Atlantic regions, ratings of fish stock status were considered consistent with FSSI scores. For the Mid-Atlantic region, respondent assessments were consistent with FSSI scores for all but two fish stocks: butterfly, *Pepilurus triacanthus*, and scup, *Stenotomus chrysops* (Fig. 1). Ratings were considered inconsistent for these two stocks primarily due to the high percentage (nearly 50%) of respondents who chose “I am unsure” for the status of these stocks. In the North Atlantic region, ratings of stock status were considered consistent with FSSI scores for all but two stocks: Atlantic herring, *Clupea harengus*, and goosefish (monkfish), *Lophius americanus*. Ratings were considered inconsistent

for goosefish due to the high percentage (> 40%) of unsure responses; however, ratings for Atlantic herring were considerably different than those assigned by the FSSI score. In November 2006, the FSSI score for Atlantic herring was four, the highest possible sustainability score. However, nearly 40% of respondents rated the status of Atlantic herring as overfished and not recovering. With the exception of the four fish stocks cited above, assessments of selected stocks were not considerably different than the assessments by NMFS.

When a respondent rated the current management of the selected stocks, ratings were excellent, good, or fair for many of the stocks.

- North Atlantic management of Atlantic sea scallops, *Plactopecten magellanicus*, received the highest rating, with nearly 54% of respondents rating management as excellent or good. Other stocks that received excellent or good management ratings included goosefish, whiting, *Merlangius merlangus*, and red hake, *Urophycis chuss*.

- Mid-Atlantic management of bluefish, *Pomatomus saltatrix*, received the highest rating, with nearly 52% of respondents rating management as excellent or good. Other stocks that received excellent or good management ratings included black sea bass, *Centropristis striata*; summer flounder, *Paralichthys dentatus*; and Atlantic mackerel, *Scomber scombrus*.
- South Atlantic management of mackerel received the highest rating, with nearly 54% of respondents rating management as excellent or good. Management received excellent or good marks for all stocks rated in this region.
- Gulf of Mexico management of red drum, *Sciaenops ocellatus*, received very high ratings, with 68% of respondents rating the management of this stock as either excellent or good. Excluding spiny lobster, *Panulirus argus*, which received a large number of unsure responses, management received excellent or good ratings for stocks rated in this region.

In addition, respondents were asked about their level of satisfaction with 22 different types of management objectives, broadly categorized as either biological/ecological, social/economic, or institutional (Tables 3 and 4). Many of these were objectives that are often discussed in relation to implementing an ecosystem approach to management. In all regions, two objectives, protect sensitive species such as marine mammals and sea turtles and maintain public access to the marine environment received excellent or good ratings by a majority (>50%) of stakeholders in the region (Table 3). In the Gulf of Mexico region, five additional objectives received excellent or good ratings.

In summary, respondents appear to have a good knowledge of the status of many of the selected stocks in their region, and in two regions, the South Atlantic and Gulf of Mexico, respondents rated management as excellent or good for most of the selected stocks. In the North Atlantic and

⁶More information on the FSSI is available at <http://www.whitehouse.gov/sites/default/files/omb/assets/OMB/expectmore/detail/10000036.2007.html> and at <http://www.nmfs.noaa.gov/sfa/statusoffisheries/SOSmain.htm> (accessed 2 Apr. 2014).

Table 3.—Management activities that received satisfactory¹ ratings from a majority (>50%) of stakeholders.

Management activity	Stakeholders (%) who rated activity as satisfactory			
	North Atlantic	Mid-Atlantic	South Atlantic	Gulf of Mexico
Protect sensitive species, such as marine mammals and sea turtles	61	55	67	64
Maintain public access to the marine environment	57	56	58	57
Ensure that regulations are monitored and enforced				56
Reduce marine pollution				54
Inform the public about the marine environment and how it is managed				52
Protect habitat necessary for fish spawning, breeding, feeding, and growth				52
Undertake research to understand relationships among different parts of the marine environment				51

¹Satisfactory is defined as a survey response of "somewhat satisfied" or "extremely satisfied."

Mid-Atlantic regions, management of one-third to one-half of the stocks received excellent or good ratings. When management was rated on 22 objectives that were more general in nature, many of which represented components of an ecosystem approach, the Gulf of Mexico fared the best, with management receiving an excellent or good rating for about one-third of the objectives.

The Bad

Management of three stocks, all in the North and Mid-Atlantic regions, was rated unsatisfactory. These stocks were groundfish and Atlantic herring, in the North Atlantic, and spiny dogfish, *Squalus acanthias*, in the Mid-Atlantic. In the North Atlantic region, 43% of respondents rated the management of groundfish as poor, and 40% rated management of Atlantic herring as poor. In the Mid-Atlantic, 37% of respondents rated the management of spiny dogfish as poor.

In general, respondents in the North, Mid-, and South Atlantic regions were less than satisfied with about a third to almost half of the management objectives they were asked to rate, depending on the region (Table 4). In the Gulf of Mexico, only two objectives received a less than satisfied rating by more than 50% of the stakeholders.

In summary, while respondents seem fairly satisfied with the management of specific stocks, in the North Atlantic, Mid-Atlantic, and South Atlantic regions they appear less than

satisfied with the way current management addresses a number of objectives. Further, many of these objectives would fit squarely within an ecosystem approach to management.

The Unsure

There were a number of stocks, especially in the North Atlantic and Mid-Atlantic regions, for which stakeholders were unsure of the performance of current management. Management of the following stocks received a rating of unsure by more than 40% of respondents in the North Atlantic or Mid-Atlantic region: red crab, *Chaceon quinque-dens*; Atlantic salmon, *Salmo salar*; skates (Rajidae); golden tilefish, *Lopholatilus chamaeleonticeps*;

squid, *Loligo pealeii* and *Illex illecebrosus*; butterflyfish, *Peprilus triacanthus*; Atlantic surfclam, *Spisula solidissima*; ocean quahog, *Arctica islandica*; and scup, *Stenotomus chrysops*. In the Gulf of Mexico and South Atlantic, about 60% and 37% of respondents, respectively, were unsure about the management of spiny lobster.

Ratings of the 22 management objectives showed that most respondents were fairly certain about their opinion of management, be it excellent/good or fair/poor. For example, no region had a proportion of unsure responses that was greater than 35%, and in each region there were only three objectives of which more than 25% of respondents said they were unsure about current management.

- North Atlantic, Mid-Atlantic, and South Atlantic objectives for which over 25% of respondents were unsure of included 1) reduce non-native species introduction, 2) set aside a portion of the fishing quota as prey for marine mammals and endangered species, and 3) allocate harvest privileges to fishermen using individual fishing quotas.
- Gulf of Mexico: objectives for which over 25% of respondents were unsure of included 1) re-

Table 4.—Management activities that received unsatisfactory¹ ratings from a majority (>50%) of stakeholders.

Management activity	Stakeholders (%) who rated activity as unsatisfactory			
	North Atlantic	Mid-Atlantic	South Atlantic	Gulf of Mexico
Minimize bycatch	59	59	58	
Maintain fishing-dependent communities	59		51	
Minimize adverse economic impacts to stakeholders	57	53		51
Restore depleted fish stocks	57	50		
Ensure that all stakeholder interests are represented in management decisions	55	55		51
Quickly adapt regulations when new scientific information becomes available	54	51	53	
Protect habitat necessary for fish spawning, breeding, feeding, and growth	54	50	54	
Maintain employment in marine-based industries	53			
Maintain the maximum sustainable yield from marine resources	53			
Protect marine biodiversity	51			
Reduce marine pollution		54	62	
Promote interagency cooperation in managing the marine environment		53	53	
Ensure that regulations are monitored and enforced			53	
Inform the public about the marine environment and how it is managed		51		

¹Unsatisfactory is defined as a survey response of "not very satisfied" or "not at all satisfied."

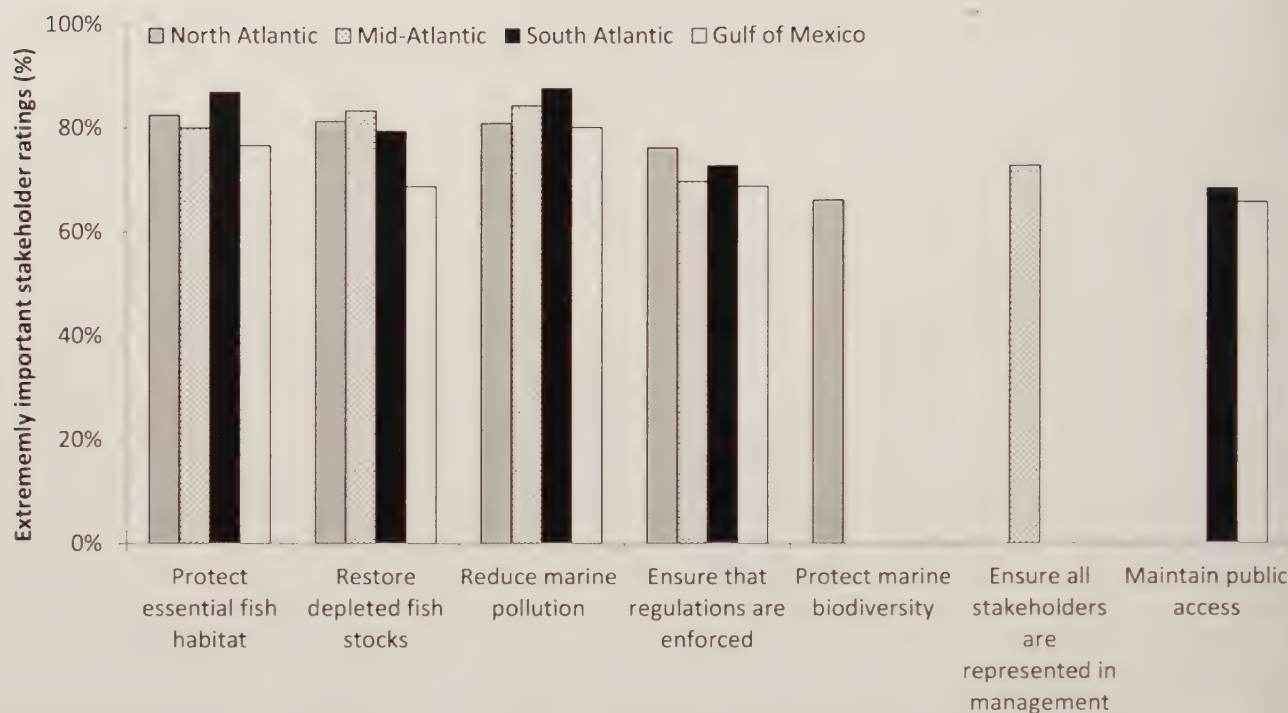


Figure 2.—Five most important management activities in each region, defined as the activities receiving the largest number of very important ratings from stakeholders.

duce non-native species introductions, 2) set aside a portion of the fishing quota as prey for marine mammals and endangered species, and 3) manage prey species so that predators have sufficient food.

What Stakeholders Want from Fisheries Management

In addition to satisfaction level, respondents were asked to rate each of the 22 management objectives as “extremely important,” “somewhat important,” “not very important,” “not important at all,” or “I am unsure” (Fig. 2). In all regions, of the top five highest-rated objectives (defined as those receiving the highest percentage of “extremely important” ratings), the top four were the same (Fig. 2). These included reducing marine pollution, protecting essential fish habitat (habitat that is essential for fish spawning, breeding, feeding, and growth), restoring depleted fish stocks, and ensuring that regulations are monitored and en-

forced. The fifth most important objectives varied by region (Fig. 2).

However, in general respondents were less than satisfied with the way management addresses these five most important objectives (Tables 3, 4). For example, in three regions, more than half of the respondents rated current management less than satisfactory when it comes to addressing the protection of essential fish habitat, reducing marine pollution, and ensuring regulations are monitored and enforced (Table 3). Restoring depleted fish stocks and reducing marine pollution was rated as important, but rated unsatisfactory when it comes to current management (Table 4).

None of management objectives were viewed by a majority of respondents as unimportant, and very few respondents were unsure of their opinion.⁷ Only three of the management

objectives received a rating of “not important at all” by 10–20% of respondents in all regions. These included reducing the total number of fishing vessels in the region, allocating harvest privileges using individual fishing quotas, and setting aside a portion of the fishing quota as prey for marine mammals and endangered species. In the Gulf of Mexico, one additional objective—managing prey species so that predators have sufficient food—was also rated as “not important at all” by about 12% of respondents. For all other objectives, less than 10% of respondents gave a “not important at all” rating.

The Outlook for an Ecosystem Approach to Management

Four of the management objectives rated by respondents rated as “ex-

⁷The percentage of “unsure” responses ranged from 1 to 17%, but on average was very low: 5% in the North and South Atlantic regions, 6% in the Mid-Atlantic region, and 8% in the Gulf

of Mexico region. Only one management activity (allocating harvest privileges using individual fishing quotas) in one region (Gulf of Mexico) received an “unsure” rating by more than 10% of stakeholders.

tremely important” fit solidly within an ecosystem-based management framework as discussed in much of the scientific literature. These include protecting essential fish habitat, protecting marine biodiversity, ensuring that all stakeholder interests are represented in management decisions, and restoring depleted fish stocks. That is not to say that these objectives are not currently incorporated into management, though some, such as protecting marine biodiversity, may receive less attention under current fisheries management than they likely would warrant with an ecosystem approach (i.e. the Intergovernmental Platform on Biodiversity and Ecosystem Services was established in April 2012 as an independent intergovernmental body to lead the assessment of biodiversity, ecosystems and the essential services they provide to society).⁸ Other objectives that would likely be typical of an ecosystem approach to management were also considered “extremely important” by more than 50% of respondents, though they were not in the top five. These include minimizing bycatch, promoting interagency cooperation in management, reducing the introduction of nonnative species, undertaking research to understand relationships between different parts of the marine environment, and protecting sensitive species such as marine mammals and sea turtles.

On the other hand, some objectives that would be considered part of an ecosystem approach received ratings of “not important at all.” For example, as stated above, managing prey species so that predators have sufficient food was rated “not important at all” by about 12% of respondents in the Gulf of Mexico, and setting aside fishing quota as prey for marine mammals and endangered species was rated “not important at all” by about 15% of respondents in all regions. This finding underscores an important point, that implementing EAFM will likely involve trade-offs between conflict-

ing objectives. As an example, while over 50% of respondents in most regions said that protecting sensitive marine species was extremely important, about 15% said that setting aside fishing quota as prey for marine mammals and endangered species was “not important at all.” Though somewhat incongruous, this finding may suggest that, in pursuing a particular objective, certain types of trade-offs might be more palatable than others (e.g. protected areas or seasonal closures may be preferable to quota set-asides).

To help managers understand what types of trade-offs stakeholders would be most likely to approve, respondents were asked to evaluate six options that may be associated with an ecosystem approach, and decide whether they were “always acceptable,” “sometimes acceptable,” “rarely acceptable,” or “never acceptable.” Stakeholders could also choose the option “I am unsure” (Fig. 3, 4, 5, 6). In general, these figures suggest that some of the trade-offs that may be required under an ecosystem approach, such as decreasing quota, limiting fishing in certain areas, and limiting gear types, are moderately acceptable to respondents in all four regions, which bodes well for implementing EAFM. It is notable that some or all of these trade-offs are currently implemented, to varying degrees, in each of the four regions.

Respondents were also asked their level of agreement with statements concerning the ability of EAFM to improve fisheries management (Tables 5, 6). In all four regions, three statements received the highest percentage of “agree” responses (EAFM would improve the overall health of marine ecosystems; EAFM would improve the status of targeted fish stocks; and EAFM would increase the protection of essential fish habitat; Table 5). For these statements, close to 80% of respondents in the North Atlantic, Mid-Atlantic, and South Atlantic regions agreed; in the Gulf of Mexico region the range was 60–70%. For all other statements the range of agree responses was 35–60%.

It is worth noting that two state-

ments (EAFM would be too complex to use as a management system and EAFM would be too costly to use as a management system), both of which illustrate a potentially negative aspect of EAFM, received the highest percentage of “disagree” responses in all regions (Table 6). In general, most respondents seemed to agree that EAFM has the potential to improve fisheries management, and for all statements except the last three, statements that illustrate potentially positive aspects of EAFM, the percentage of disagreeing respondents was 9–26%.

Compared to other sections of the survey, respondents seemed more unsure of their opinions concerning the potential for EAFM. For example, for every statement, at least 10% of respondents in each region chose the response “I am unsure,” and, on average, the unsure response was 20% in the North and Mid-Atlantic regions, 17% in the South Atlantic region, and 24% in the Gulf of Mexico region. All of the above results may suggest cautious optimism toward implementing an ecosystem approach to management along the U.S. East and Gulf coasts.

Conclusion

It is fair to say that fisheries stakeholders in the North Atlantic, Mid-Atlantic, South Atlantic, and Gulf of Mexico regions have a fairly accurate knowledge of the status of fish stocks in their regions, at least those selected for this survey. Further, stakeholders are relatively satisfied with current management of those stocks, with a few exceptions. However, when it comes to more general types of management activities, stakeholders, particularly those in the North, Mid, and South Atlantic regions, generally have a less than good opinion of management.

On the positive side, many of the objectives that stakeholders believe are extremely important are representative of EAFM, and perhaps the transition to that approach will meet with minimal to moderate resistance. Trade-offs, however, will be a key challenge

⁸For more information, see <http://www.ipbes.net/about-ipbes.html> (accessed 2 Apr. 2014).

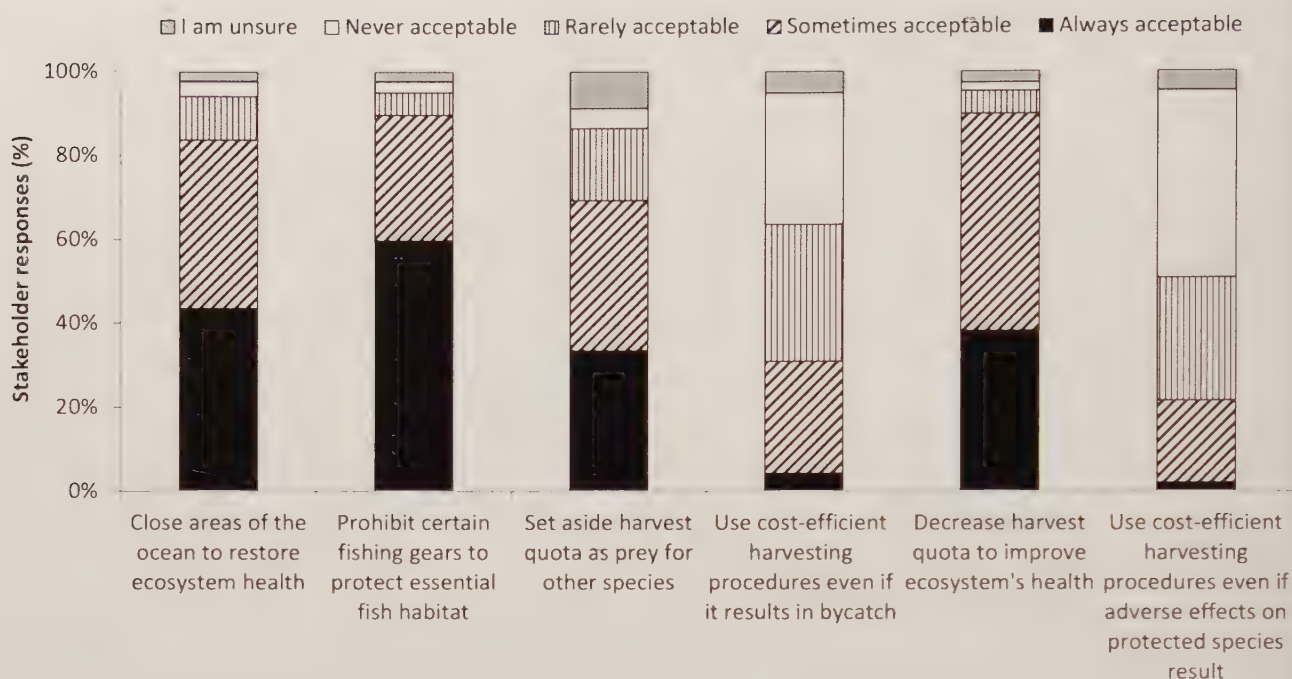


Figure 3.—Acceptable trade-offs in the North Atlantic region.

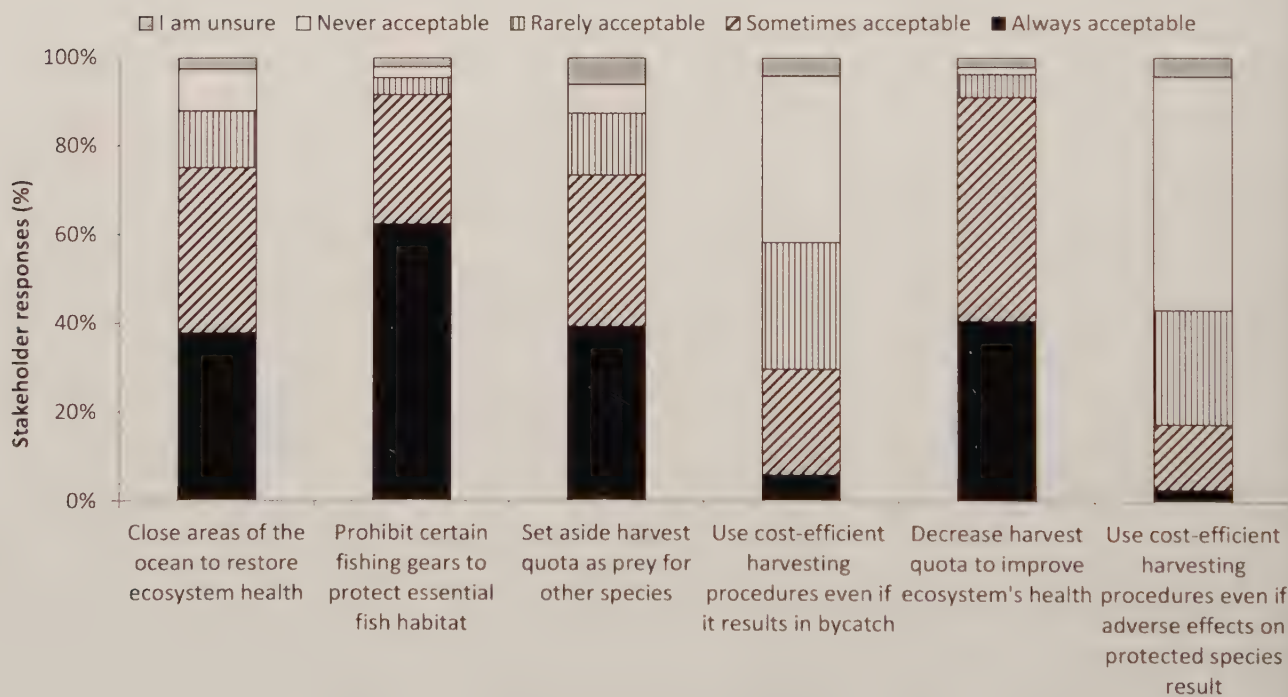


Figure 4.—Acceptable trade-offs in the Mid-Atlantic region.

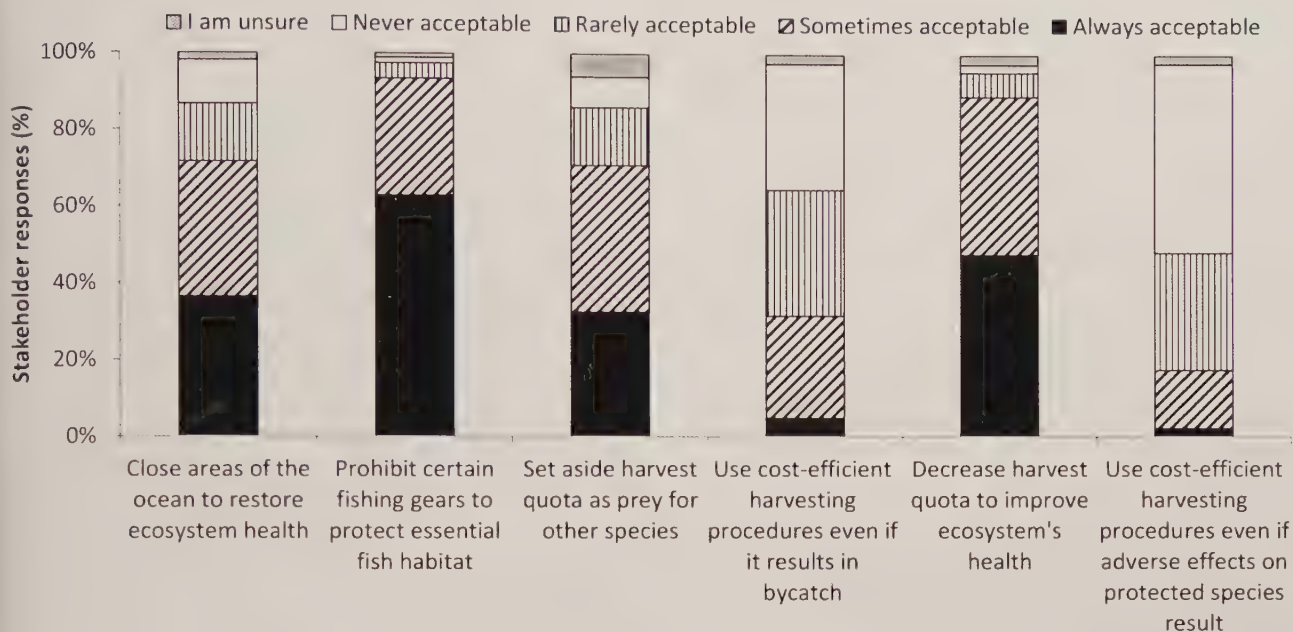


Figure 5.—Acceptable trade-offs in the South Atlantic region.

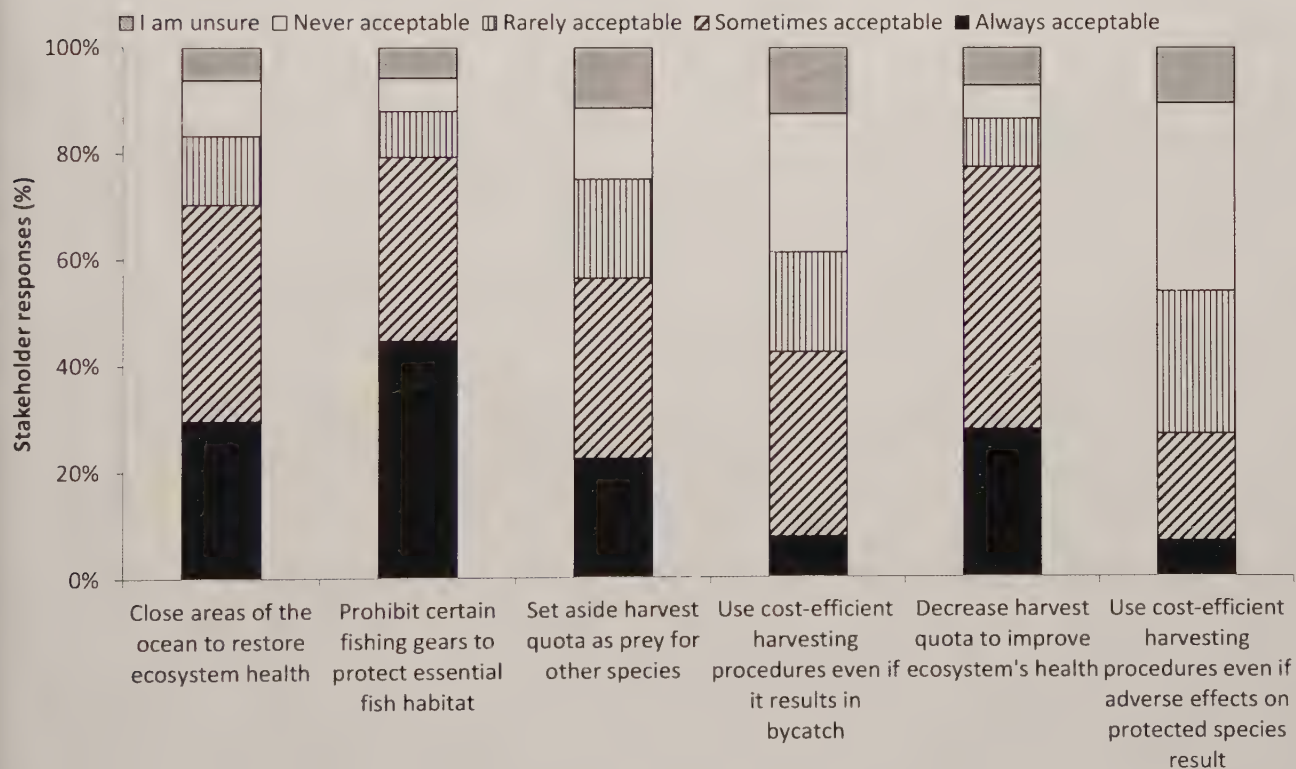


Figure 6.—Acceptable trade-offs in the Gulf of Mexico region.

Table 5.—Stakeholders who agree with certain ecosystem management principles.

Management activity	Stakeholders (%) who agreed ¹ with principle			
	North Atlantic	Mid-Atlantic	South Atlantic	Gulf of Mexico
EAM would improve the overall health of marine ecosystems	79	79	77	72
EAM would increase the overall profits in the region's fisheries	52	49	46	52
EAM would benefit fishing communities	64	64	61	55
EAM would improve the status of targeted fish stocks	75	75	71	64
EAM would increase the protection of Essential Fish Habitat	75	77	74	61
EAM would improve the status of marine mammals and sea turtles	68	69	64	60
EAM would be more representative of all types of fisheries stakeholders than the current management system	50	50	48	46
EAM would be too complex to use as a management system	40	41	42	43
EAM would be too costly to use as a management system	35	37	34	36

¹The option "I am unsure" was also available.

in EAFM implementation, and while these results suggest that stakeholders were willing to make some types of trade-offs, only a handful of trade-offs were presented in the survey. In reality, implementation may require that a much larger array of trade-offs be evaluated. That said, stakeholders' cautious optimism for EAFM, perhaps fueled by some level of dissatisfaction with current fisheries management, suggests moving forward.

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Table 6.—Stakeholders who disagree with certain ecosystem management principles.

Management activity	Stakeholders (%) who disagreed ¹ with principle			
	North Atlantic	Mid-Atlantic	South Atlantic	Gulf of Mexico
EAM would improve the overall health of marine ecosystems	9	11	12	11
EAM would increase the overall profits in the region's fisheries	27	30	31	27
EAM would benefit fishing communities	19	21	22	26
EAM would improve the status of targeted fish stocks	11	11	15	16
EAM would increase the protection of Essential Fish Habitat	10	12	12	17
EAM would improve the status of marine mammals and sea turtles	12	16	15	20
EAM would be more representative of all types of fisheries stakeholders than the current management system	28	30	30	24
EAM would be too complex to use as a management system	35	35	34	26
EAM would be too costly to use as a management system	31	34	36	28

¹The option "I am unsure" was also available.

Ecosystem Management Survey

Help us improve fisheries management.



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Questions? Email Kristy.Wallmo@noaa.gov
This survey is voluntary.
All responses are anonymous and confidential.

OMB Control Number 0648-0523 expires 12/30/08

Section A: Interest in Fisheries Management.

NOAA's National Marine Fisheries Service is asking a sample of fisheries stakeholders about their attitudes toward Ecosystem Approaches to Fisheries Management, or EAFM. Please take a few minutes to complete the survey - we want an Ecosystem Approach to Fisheries Management to reflect the preferences of fisheries stakeholders. We would like to begin by asking you a few questions about your personal or professional interest in fisheries management. When completing the questionnaire please print clearly.

Your opinions are important!

- A1 During the past year, how many meetings of the following types have you attended?
- _____ Fishery management councils, subcommittee or advisory committees
_____ Environmental organizations
_____ Recreational fishing clubs or associations
_____ Commercial fishing trade organizations
_____ Other (please specify) _____
- A2 Do you or does anyone in your household make a living part-time or full-time from work directly associated with marine resources or the marine environment?
- ☐ Yes
☐ No
☐ I am unsure
- A3 Have you seen, heard, or read about fisheries management in the past 3 years?
- ☐ Yes
☐ No
- A4 Have you ever altered your recreation or vacation plans because of fisheries management decisions or fisheries regulations?
- ☐ Yes
☐ No
- A5 How concerned are you that fisheries management decisions will impact your life or livelihood?
- ☐ Very concerned
☐ Somewhat concerned
☐ Not concerned at all
☐ I am unsure

Questions? email us at Kristy.Wallmo@noaa.gov

2

Section B: Current Fisheries Management in the Gulf of Mexico

In this section, we would like to know what you think about the current status of some marine fish and other animals in the Gulf of Mexico region, which includes the marine waters off the coast of West Florida, Alabama, Mississippi, Louisiana, and Texas. Please answer the questions below based on your opinions and knowledge of the Mid-Atlantic region.

- B1 In your opinion, current management of this species is....

	Excellent	Good	Fair	Poor	I am unsure
Bottlenose Dolphin	☐	☐	☐	☐	☐
Sea Turtles	☐	☐	☐	☐	☐

- B2 In your opinion, the status of this species is....

	Stable	Threatened or endangered but recovering	Threatened or endangered not recovering	I am unsure
Bottlenose Dolphin	☐	☐	☐	☐
Sea Turtles	☐	☐	☐	☐

- B3 In your opinion, current management of this species is....

	Excellent	Good	Fair	Poor	I am unsure
Red Drum	☐	☐	☐	☐	☐
Spiny Lobster	☐	☐	☐	☐	☐
Snappers/Groupers	☐	☐	☐	☐	☐
Mackerels	☐	☐	☐	☐	☐
Shrimp	☐	☐	☐	☐	☐

Questions? call Kristy Wallmo at 1.301.713 2328

3

Questions? email us at Kristy.Wallmo@noaa.gov

4

Section C: Your Preferences for Fisheries Management

A number of objectives can be considered when fisheries management strategies are developed for the Gulf of Mexico region, and, in some cases, objectives will be conflicting. Because not all objectives can be given equal attention, it is important for managers to understand which objectives are important to you.

C1 Listed below are a number of potential objectives for managing the Gulf of Mexico region. Using the scales, please circle your opinion about:

- The importance of each objective for the Gulf of Mexico region
- The satisfaction level you have with the way current management addresses each objective in the Gulf of Mexico region

Importance	Satisfaction
1=Extremely Important	1=Extremely Satisfied
2=Somewhat Important	2=Somewhat Satisfied
3=Not Very Important	3=Not Very Satisfied
4=Not Important at All	4=Not Satisfied at All
5=I Am Unsure	5=I Am Unsure

(a) Ensure that all stakeholder interests are represented in management decisions	1 2 3 4 5	1 2 3 4 5
(b) Maintain employment from marine-based industries	1 2 3 4 5	1 2 3 4 5
(c) Protect marine biodiversity	1 2 3 4 5	1 2 3 4 5
(d) Restore fish stocks that have been depleted	1 2 3 4 5	1 2 3 4 5
(e) Reduce pollution in the marine environment	1 2 3 4 5	1 2 3 4 5
(f) Protect sensitive species such as marine mammals and sea turtles	1 2 3 4 5	1 2 3 4 5
(g) Minimize any adverse economic impacts to stakeholders	1 2 3 4 5	1 2 3 4 5
(h) Protect Essential Fish Habitat - habitat that is necessary for fish spawning, breeding, feeding, and growth	1 2 3 4 5	1 2 3 4 5

Questions? call Kristy Wallmo at 1 301.713 2328

C1 Continued...

Importance	Satisfaction
1=Extremely Important	1=Extremely Satisfied
2=Somewhat Important	2=Somewhat Satisfied
3=Not Very Important	3=Not Very Satisfied
4=Not Important at All	4=Not Satisfied at All
5=I Am Unsure	5=I Am Unsure

(i) Minimize bycatch	1 2 3 4 5	1 2 3 4 5
(j) Maintain public access to the marine environment	1 2 3 4 5	1 2 3 4 5
(k) Set aside a portion of the fishing quota for marine mammals and endangered species to eat	1 2 3 4 5	1 2 3 4 5
(l) Undertake research to understand the relationships among different parts of the marine environment	1 2 3 4 5	1 2 3 4 5
(m) Promote interagency cooperation in managing the marine environment	1 2 3 4 5	1 2 3 4 5
(n) Maintain the maximum sustainable yield from marine resources	1 2 3 4 5	1 2 3 4 5
(o) Reduce non-native species introductions	1 2 3 4 5	1 2 3 4 5
(p) Quickly adapt regulations when new scientific information becomes available	1 2 3 4 5	1 2 3 4 5
(q) Undertake activities to inform the public about the marine environment and how it is managed	1 2 3 4 5	1 2 3 4 5
(r) Allocate harvest privileges to fishermen using Individual Fishing Quotas	1 2 3 4 5	1 2 3 4 5
(s) Manage prey species so that predators have sufficient food	1 2 3 4 5	1 2 3 4 5
(t) Maintain fishing-dependent communities	1 2 3 4 5	1 2 3 4 5
(u) Ensure that regulations are monitored and enforced	1 2 3 4 5	1 2 3 4 5
(v) Reduce the total number of fishing vessels	1 2 3 4 5	1 2 3 4 5

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6

C2 For the next set of questions, we would like you to read each statement below and place a check in the one box that most closely represents your opinion

	Always	Sometimes	Rarely	Never	I am unsure
(a) It is acceptable to decrease fish harvest quotas in order to improve the overall health of the marine environment	☐	☐	☐	☐	☐
(b) It is acceptable to preserve marine-based employment opportunities even if doing so decreases the overall profits from marine-based industries	☐	☐	☐	☐	☐
(c) It is acceptable to set aside some of the harvest quota in order to maintain a food source for higher level fish and mammals	☐	☐	☐	☐	☐
(d) It is acceptable to use cost-efficient harvesting procedures even if doing so results in the bycatch of non-targeted species	☐	☐	☐	☐	☐
(e) It is acceptable to use cost-efficient harvesting procedures even if doing so has adverse effects on protected marine species	☐	☐	☐	☐	☐
(f) It is acceptable to allocate harvest privileges such as Individual Fishing Quotas even if doing so has adverse social effects on fishing communities	☐	☐	☐	☐	☐
(g) It is acceptable to discard harvested fish due to regulatory restrictions, even when those fish may be marketable	☐	☐	☐	☐	☐
(h) It is acceptable to prohibit certain types of fishing gear in order to protect essential fish habitat	☐	☐	☐	☐	☐
(i) It is acceptable to close areas of the ocean to fishing in order to restore ecosystem health	☐	☐	☐	☐	☐
(j) It is acceptable to discard harvested fish if they do not have a market value	☐	☐	☐	☐	☐

Questions? call Kristy Wallmo at 1 301 713 2328

Section D: Ecosystem Approaches to Fisheries Management

In this section, we would like to ask you about your opinions of an Ecosystem Approach to Fisheries Management, or EAFM.

An ecosystem is a geographically specified system of organisms, including humans, and the processes that shape the system. Most scientists agree that an Ecosystem Approach to Fisheries management would consider the following elements:

- Extension of the single-species approach of current fisheries management to also consider ecological relationships such as predation, competition, and habitat.
- Consideration of the overall quality of the marine ecosystem.
- Consideration of humans as part of the ecosystem.
- Promotion of integrated, regional management of marine ecosystems with all relevant authorities and stakeholders.
- Use of the precautionary approach, e.g. make conservative decisions when information is uncertain or incomplete.
- Initiate activities to increase the knowledge base available for decision-making.
- Try to balance diverse societal objectives.

D1 For the next set of questions, we would like you to read each statement below and please check the box corresponding to your level of agreement with that statement

In the Gulf of Mexico region EAFM...

	Strongly Agree	Somewhat Agree	Somewhat Disagree	Strongly Disagree	I am unsure
would improve the overall health of marine ecosystems	☐	☐	☐	☐	☐
would increase the overall profits in the region's fisheries	☐	☐	☐	☐	☐
would benefit fishing communities	☐	☐	☐	☐	☐
would improve the status of targeted fish stocks	☐	☐	☐	☐	☐

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8

Section E: About You and Your Household

In this last section, we would like to ask you a few questions about yourself.

- E1** In general, how important are each of the following reasons for choosing to visit or live in a coastal community?

	Very Important	Somewhat Important	Not Very Important	Not Important at All
Visit family and friends	☐	☐	☐	☐
Visit a natural area	☐	☐	☐	☐
Recreational fishing	☐	☐	☐	☐
Commercial fishing	☐	☐	☐	☐
View marine animals (such as whales, sea turtles, manatees, etc.)	☐	☐	☐	☐
Snorkeling or diving	☐	☐	☐	☐
Birding	☐	☐	☐	☐
Hunting	☐	☐	☐	☐
Buy fresh local seafood	☐	☐	☐	☐
Enjoy being around a working commercial fishing manna/dock	☐	☐	☐	☐
Other reasons (please specify):	☐	☐	☐	☐

- E2** During the past year, how many days have you spent

☐ Recreational fishing in freshwater
☐ Recreational fishing in saltwater
☐ Collecting shellfish or other marine resources for personal consumption
☐ Participating in marine-based recreation such as visiting a beach, boating, sightseeing, snorkeling, scuba diving, whale watching, etc.
☐ Commercial fishing in saltwater
☐ Providing marine recreational services for hire (charter or headboat fishing, whale watching, sightseeing, etc.)

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10

- E7** Which of the following categories best describes your household's total annual income before taxes in 2005?

☐ Less than \$10,000 ☐ \$50,000 - \$74,999
☐ \$10,000 - \$14,999 ☐ \$75,000 - \$99,999
☐ \$15,000 - \$24,999 ☐ \$100,000 - \$149,999
☐ \$25,000 - \$34,999 ☐ \$150,000 - \$199,999
☐ \$35,000 - \$49,999 ☐ \$200,000 or more

- E8** What is your ethnic background?

☐ Hispanic or Latino ☐ Not Hispanic or Latino

- E9** What is your race (please mark all that apply)?

☐ White ☐ American Indian or Alaska Native
☐ Black/African American ☐ Native Hawaiian or Other Pacific Islander
☐ Asian

- E10** What year were you born?

Year _____

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12

- E3** How much do you trust each of the following to manage marine resources? Please check the box that most closely represents your opinion:

	Trust completely	Trust somewhat	Distrust somewhat	Don't trust at all	I am unsure
Federal agencies	☐	☐	☐	☐	☐
State agencies	☐	☐	☐	☐	☐
Local governments	☐	☐	☐	☐	☐
Scientists	☐	☐	☐	☐	☐
Independent boards made up of local interests	☐	☐	☐	☐	☐
Independent boards with business and environmental interests	☐	☐	☐	☐	☐

- E4** What is the highest level of education you have completed?

☐ Less than 9th grade ☐ Some college (no degree)
☐ Some high school (no diploma) ☐ College graduate (bachelor degree)
☐ High school graduate (including GED) ☐ Advanced, Professional, or doctoral degree
☐ Associates degree or technical school

- E5** Are you.....?

☐ Male ☐ Female

- E6** What best describes your employment status? Please check all that apply

☐ Employed full-time ☐ Student (part-time)
☐ Employed part-time ☐ Student (full-time)
☐ Full time homemaker ☐ Unemployed
☐ Retired ☐ Other (specify) _____

Questions? call Kristy Wallmo at 1.301.713.2328

11

- D2** For the next set of questions, we would like you to read each statement below and please check the box corresponding to your level of agreement with that statement:

In the Gulf of Mexico region EAFM...

	Strongly Agree	Somewhat Agree	Somewhat Disagree	Strongly Disagree	I am unsure
...would increase the protection of Essential Fish Habitat	☐	☐	☐	☐	☐
...would improve the status of marine mammals and sea turtles	☐	☐	☐	☐	☐
...would be more representative of all types of fisheries stakeholders than the current management system.	☐	☐	☐	☐	☐
...would be too complex to use as a management system	☐	☐	☐	☐	☐
...would be too costly to use as a management system	☐	☐	☐	☐	☐

Marine managers are increasingly adopting an Ecosystem Approach to Fisheries Management, though there is still discussion about the concept itself and how it should be implemented. Please use the space below to tell us any thoughts or opinions that you have about an EAFM.

Questions? call Kristy Wallmo at 1.301.713.2328

9

- ☐ Commercial fisherman
- ☐ Recreational fisherman
- ☐ Concerned Citizen
- ☐ Member of an environmental organization
- ☐ Member of a fisheries trade organization
- ☐ Fishery manager
- ☐ Fishery researcher
- ☐ Academic (teacher, researcher)
- ☐ Government agency personnel
- ☐ Other (specify) _____

- ☐ Television
- ☐ Radio
- ☐ Newspapers
- ☐ Fishing websites
- ☐ Magazines
- ☐ Clubs/associations
- ☐ Email from friends
- ☐ Email from organizations
- ☐ Government announcements
- ☐ Other (specify) _____

Questions? call Kristy Wallmo at 1.301.713.2328

Thank You for Participating!

Please use the space below to make any additional comments you may have. If you have any questions regarding the survey, please call 1.301.713.2328 or email Kristy.Wallmo@noaa.gov

PAPERWORK REDUCTION ACT STATEMENT: Collection of information through exit surveys provides data on preferences for fishery management goals and objectives from a diverse group of fisheries stakeholders. This information aids NOAA Fisheries in developing and analyzing an array of fishery management guidelines and policies. Public reporting burden is estimated to average 20 minutes per response. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to: NOAA Fisheries, Ft. 573, 1205 East Highway, Silver Spring, MD 20910.

Providing the requested information is voluntary. In accordance with NOAA Administrative Order 276-100, "Confidentiality of Fishery Statistics" any information submitted to NOAA Fisheries by any person in response to this survey shall be considered confidential and shall not be disclosed except to: (1) those employees and council employees who are responsible for fishery management plan development and monitoring; (2) state departments pursuant to an agreement with the Secretary of Commerce that prevents public disclosure of this information; or (3) when required by court order. Notwithstanding any other provision of the law, no person is required to respond to, nor shall any person be subject to a penalty for failure to respond to, this survey in compliance with a collection of information subject to the requirements of the Response Reduction Act, unless that collection of information displays a currently valid OMB Control Number. This is an approved information collection under OMB0546-0071.

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Evaluation of Fishing Opportunities under Sea Turtle Interaction Limits —A Decision Support Model for Hawaii-based Longline Swordfish, *Xiphias gladius*, Fishery Management

MINLING PAN and SHICHAO LI

Introduction

The Hawaii shallow-set longline fishery primarily targets swordfish, *Xiphias gladius*, in waters north of the Hawaiian Archipelago. These fishing grounds are also key pelagic habitat for protected species of sea turtles, particularly loggerhead sea turtles, *Caretta caretta*, and occasionally longline vessels will incidentally catch them. In 2004, under provisions of the Endangered Species Act, NOAA's National Marine Fisheries Service (NMFS) issued a series of regulations for the fishery including caps on incidental captures of sea turtles (called sea turtle "interactions") allowed each year (NOAA, 2009). These regula-

tions included an annual fishing effort limit which is the total number of fishing days (sets) that the fleet could utilize throughout the year. If and when the fleet-wide fishing effort limit is reached, or the incidental sea turtle catch limit is reached, NMFS will close the swordfish fishery for the remainder of the year. Subject to these constraints, and other regulations, swordfish vessels are free to set their gear in any month and anywhere in the swordfish grounds.

The location and timing of swordfish fishing operations has consequences for sea turtles as well as for the economic returns of the vessels. Decisions on where and when to fish take into account expected swordfish catch rates and may take into account the likelihood of interactions with sea turtles, both of which vary spatially and temporally, as well as the costs incurred in fishing, which are largely a function of trip length (days) and distance of fishing locations from port.

Two natural questions that arise are "can sea turtle hot spots be identified

and avoided without reduced or negative impact on the economic returns of the fishery?" And, if so, "what time-area fishing strategy should be pursued to maximize net economic returns subject to the fleet-wide constraint on turtle interactions and fishing effort?" To study these questions from a fleet-wide perspective, a bioeconomic model was developed and used to examine trade-offs between the risk of interacting with sea turtles and economic returns to the fleet (Li and Pan, 2007).

This paper describes the bioeconomic model and demonstrates how it can be applied to evaluate potential policy choices. The model was used to search for possible policy alternatives in order to maximize swordfish fishing opportunities subject to the constraints on fishing effort and the annual cap on interactions with loggerhead sea turtles. If the swordfish fishery is closed, Hawaii longline fishermen who are engaged in the shallow-set fishery for swordfish can redirect their effort to target bigeye tuna, *Thunnus obesus*, using deep-set longline gear. Thus, the foregone swordfish fishing opportunity may not have a negative impact on the Hawaii longline fishery if fishermen could continue their fishing operation by targeting bigeye tuna for the remainder of the year (at some fixed and operational costs).

However, the fishery also faces restrictions on bigeye tuna due to overfishing of the stocks in the Pacific Ocean.¹ Reduced fishing opportuni-

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ABSTRACT—Conservation measures of setting annual caps on sea turtle, *Cheloniidae*, interactions and other regulations have resulted in a significant reduction in sea turtle interactions in the Hawaii-based longline fishery. On the other hand, the conservation measures created a limitation on swordfish, *Xiphias gladius*, production and created uncertainty for participants in the fishery because the fishery would be closed whenever the cap is reached. This study explores the trade-offs between the risks of sea turtle interactions and economic returns from swordfish fishing, and identifies examples of alternative management options that could allow the swordfish fishery to operate throughout the year with

a reduced risk of exceeding the cap on loggerhead sea turtle, *Caretta caretta*, interactions. In addition, the study compares the trade-offs in terms of foregone swordfish production based on one interaction reduction before and after the implementation of the conservation measures. A spatial bioeconomic model is developed to conduct simulation analyses. A Generalized Additive Model (GAM) is applied to Hawaii longline logbook data to examine and predict sea turtle interactions in response to changes in spatial and temporal distributions of fishing effort and oceanographic conditions. A cost function is built into the model for making economic analyses to estimate net revenue returns.

¹Bigeye catch limits imposed on the Hawaii longline fishery are determined by two Regional Fisheries Management Organizations (RFMO's): the Western and Central Pacific Fisheries Commission (WCPFC) and the Inter-American Tropical Tuna Commission (IATTC). Each RFMO allocates a region-specific bigeye quota for the U.S. pelagic longline fishery operating in its

ties in the tuna sector caused by big-eye tuna quotas imply an increased importance of fishing opportunities in the swordfish sector. Therefore, developing an analytical tool that facilitates the formulation of an ecologically sustainable and responsible fishery for swordfish is of vital importance for Hawaii's longline fishery as a whole.

A Generalized Additive Model (GAM) was developed by Kobayashi and Polovina (2005) to predict sea turtle interaction rates by month and location. The model was used to estimate the impacts on the fishery landings and sea turtle interactions for certain area closures. However, the model has several limitations, such as omitting fishing costs, and the spatial and temporal variations of fish catch rates. Modifications were made to improve the model for this policy analysis.

For example, the NMFS Turtle-Watch Program (Howell et al., 2008) generates maps of sea surface temperature in the Hawaii longline swordfish fishing grounds and delineates areas where interactions with sea turtles are considered most likely to occur. If these areas with high interaction rates are closed to the fishery, what would be the economic impact to the fishery, and would the sea turtle interactions be at risk to exceed the caps or not?

This study aims to develop a model to enhance quantitative analyses for the decision-making process. We proceed by updating and modifying the GAM model, illustrating the trade-offs between sea turtle interactions and economic returns under different fishing operations, and then search for optimal policy options with different area closure and/or seasonal closures.

Model Development

Loggerhead sea turtle interactions were the main concern to the Hawaii longline swordfish fishery due to the high interaction rate, even though the fishery also interacted with other

sea turtles. Because areas with high catch rates of swordfish often overlap with loggerhead sea turtle habitat, the optimization of a time-area fishing strategy involves a trade-off between potential economic returns and impacts on the turtles.

To help understand the trade-off, we developed a spatial and temporal model of longline–turtle interactions that would enable prediction of sea turtle interaction rates associated with each unit of swordfish fishing effort and the economic returns of the fishing effort by area and time. The model was developed to predict sea turtle interaction rates because sea turtle interactions were a rare event and no complete record of longline–turtle interactions existed for all fishing trips, only those monitored through the observer program administered by the NMFS Pacific Islands Regional Office.

We used the GAM approach developed by Kobayashi and Polovina (2005) to build a spatial and temporal bio-economic model to predict sea turtle interaction rates by month and location of fishing, and to evaluate the policy options of time-area closures to reduce the overall level of interactions. There are several limitations in the Kobayashi and Polovina (2005) model, so modifications were made to improve the model for the policy analysis.

First, this study developed the GAM to predict fish catch per unit of effort (CPUE) (measured per 1,000 hooks in this study) by month and location of fishing, for the targeted species (swordfish) and other fish species caught during the fishing trip. Thus, the revenue associated with the fishing effort in different times and areas can be calculated with fish catch and fish price data, reflecting the spatial and temporal variation of fish catch rates. Economic returns are represented by ex-vessel net revenue² per 1,000 hooks

deployed. Kobayashi and Polovina (2005) used GAM fitted to the data to predict turtle interactions given specified levels of fishing effort over the entire longline fleet, assuming no spatial and temporal variations for fishing effort and CPUE.

In the analysis of Kobayashi and Polovina (2005), economic returns in the longline fleet were based only on revenue. A better measure of economic returns would take into account fishing costs, in particular the costs of travel to and from the fishing grounds, which can be greatly affected by time-area regulations, fish distribution, fuel costs, and other factors. Even a 1-day increase in travel time per trip can result in a significant loss in net annual revenue (Hamilton et al., 1996).

To incorporate such economic factors, we used trip cost data for the period of 2005–06 gathered with an economics data collection program established through a collaboration between the NMFS Pacific Islands Fisheries Science Center (PIFSC) Economics Program and the Pacific Islands Regional Office (PIRO) (Pan et al.³) and developed a cost function associated with each production unit (fishing trip). The summary of the cost data was posted on the PIFSC website (PIFSC⁴) although the details of individual trips and the associated revenue

cies in total) from Hawaii longline logbook data were calculated based upon 2005 Honolulu auction data (source: Pac. Isl. Fish. Sci. Cent. unpubl. confidential data). The cost of each fishing trip was estimated from the regression model based on its set type, fishing days, vessel length, and average distance from set location to the port of landing recorded in the fishermen's logbooks. Economic returns in net revenue for each effort unit (set) was then calculated from ex-vessel revenue by subtracting the estimated variable costs, and then adjusted for the number of hooks deployed in the set.

³Pan M., H. L. Chan, and K. Kalberg. 2012. Tracking the changes of economic performance indicators for the main U.S. commercial fisheries in the Pacific Islands Region. Pac. Isl. Fish. Sci. Cent. Inter. Rep. IR-12-039, Issued 15 Oct. 2012, 18 p.

⁴PIFSC. 2011. Data summary of the unpublished confidential data was presented in the economic performance of Hawaii longline fishery. Pac. Isl. Fish. Sci. Cent. rep. online at: http://www.pifsc.noaa.gov/economics/economic_performance_of_the_hawaii_longline_fishery.php, accessed 1 Apr. 2014.

area of jurisdiction. The Eastern Pacific Ocean quota was 150 t during 2004–06, and 500 t after 2007 (applied to vessels that were longer than 24 m). The annual bigeye tuna quota had been 3,763 t since 2009 and further declined in 2015.

²The ex-vessel revenue of each set was calculated by using the monthly piece value for each species of fish sold (\$/fish using fish auction data) multiplied by the number of fish caught and kept for a particular set as recorded in Hawaii longline logbook datasets (unpubl. confidential data by PIFSC). Monthly ex-vessel piece values of all the species caught and sold (28 spe-

Table 1.—Regression coefficients of the log-transformed trip-cost function.¹

Variables	Coefficients	Standard error	P-value	Adjusted R ²
Intercept	3.50558	0.0504	0.000	0.803
Fishing days (#sets)	0.02126	0.0021	0.000	
Average-distance (Miles from port)	0.00012	3.4E-05	0.001	
Vessel length (feet)	0.00529	0.0008	0.000	
Set type	0.19984	0.0195	0.000	

¹Cost per (fishing) trip as a function of predictor variables. Number of observed trips = 181. Set type is a dummy variable (deep set = 0; shallow set = 1) in the model. P-values indicate all variables are significant at least 99% confidence level. Data source: Data of trip cost, fishing days, and travel distance were from PIFSC unpublished confidential data.

were not published since they were confidential data.

Table 1 shows the results of a linear regression analysis on the cost function for the fishery based on 181 observed trips, including both shallow-set swordfish trips and deep-set tuna trips, which revealed that trip costs were significantly affected by set type (targeting tuna or swordfish), days of fishing per trip, vessel size (length), and the average distance to port from the fishing location. The predictor variables are available from the mandatory logbooks of daily fishing activity submitted to NMFS by vessel captains or in NMFS permit databases, or can be calculated from such information.

Therefore, using the cost function resulting from the regression analysis (Table 1), the cost of each fishing trip of the fleet can be estimated based on its set type, trip days, vessel size, and the distance from port. Using this as the cost function incorporated into the spatial and temporal GAM model, the economic return of fishing effort was measured by net revenues², (\$/1,000 hooks deployed). Because monthly prices and fish catch rate were used in the revenue calculation, the variation of revenue across months was considered in the model.

Lastly, data for the period of 2000–06 were included in the model. Kobayashi and Polovina (2005), using 1994–99 observer data, examined sea turtle interactions in relation to oceanographic conditions and spatial and temporal distributions of fishing effort. The Hawaii longline fishery experienced many changes, including the closure of the swordfish fishery in 2000 and its reopening in 2004, resulting in much lower sea turtle in-

teraction rates than prior to 2000. In addition, the focus of this study was on the swordfish fleet using shallow-set gear, while the Kobayashi and Polovina (2005) model used all the observed Hawaii longline fishing operations, including those by vessels using deep-set gear to target bigeye tuna along with those using shallow-set gear to target swordfish.

Based on our modified GAM model with updated data in this study, loggerhead turtle interactions were found to be significantly associated with many factors including: season (month) and year, latitude and longitude of fishing, type of longline set (either a deep-set operation for tuna or shallow-set operation for swordfish), sea surface temperature, and even moon phase. The variables significantly associated with loggerhead interaction rates were consistent with those found by Kobayashi and Polovina (2005).

The updated GAM is used to es-

timate turtle interactions per unit of fishing effort (longline set) in different locations (using one degree by one degree latitude/longitude squares) and in different months. Hence, model predictions can be generated for the total number of sea turtle interactions that might be expected for any given effort level (total number of swordfish sets) and any given effort distribution across months and locations. Thus, the model can be used to investigate the trade-offs between sea turtle interactions and economic returns to the fishery for different policy simulations and search for the possible optimal solutions under the two conflict management goals of maximum fishery economic return and minimum sea turtle interactions.

Simulations and Results

The Trade-offs Among Seasons and Areas

Because of the spatial and temporal variations in sea turtle interaction rates and economic returns, the model predicted different economic returns and turtle interaction levels between seasons and areas. The model results show that sea turtle interactions and economic returns showed similar patterns (increasing or decreasing together) in some months, but showed different patterns in other months (Fig. 1).

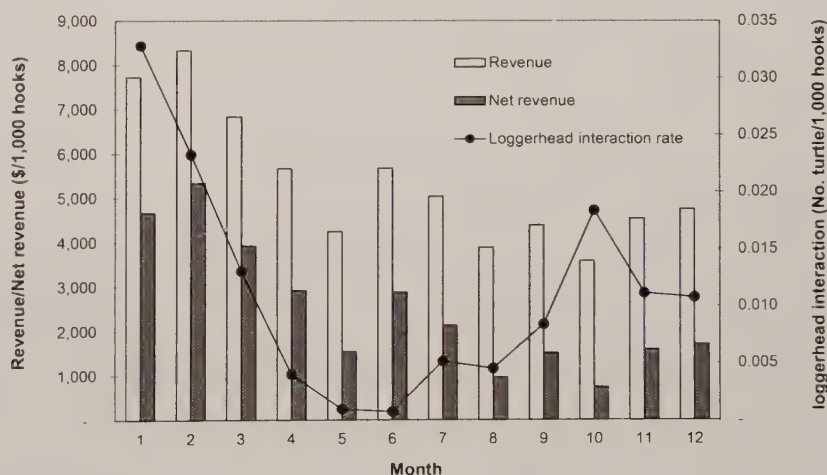


Figure 1.—Economic returns and loggerhead turtle interactions across a 12-month period.

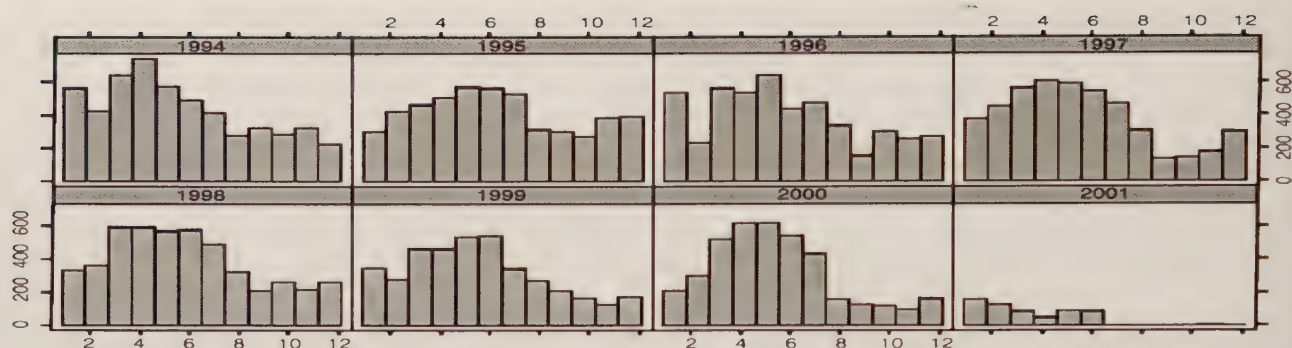


Figure 2.—Monthly distribution of swordfish fishing effort (shallow sets) across years (1994–2001).

For example, the highest net revenue per unit of effort occurs in February, while the highest loggerhead turtle interaction rate occurs in January. Thus, the trade-off (i.e., the number of sea turtle interactions for a given level of economic returns) varies by months.

In the first quarter (Jan.–Mar.), economic returns are high and loggerhead turtle interaction rates in those months are also high. In the second quarter (April–June), turtle interaction rates are at their lowest level, but economic returns are relatively high. Therefore, the trade-offs would be relatively low in the second quarter, compared to the first quarter. Prior to 2000 when the fishery was closed, the swordfish fishing efforts allocated were usually highest in the second and first quarters, 36% and 27%, respectively, compared to the third and fourth quarters (Fig. 2). However, after the fisheries reopened in 2005 with the cap in efforts allowed, most of the swordfish fishing efforts occurred in the first quarter. As shown, fishing in the first quarter results in higher net economic returns to the fishery, but the risk of exceeding sea turtle caps is also higher, compared to the other seasons.

Economic return and sea turtle interactions also varied by fishing location. Figure 3 shows the spatial variations in sea turtle interaction rates and economic returns. For example, in lower latitude areas (< lat. 28°N), the loggerhead sea turtle interaction rate is relatively low compared to economic returns. Thus, the expected trade-off (the number of sea turtle interactions

for a given level of economic return) would be relatively small.

Both loggerhead sea turtle interaction rates and economic returns increase north of lat. 20°N up to lat. 32°N, with loggerhead sea turtle interaction rates increasing more steeply than economic returns. The peak of the loggerhead turtle interaction rate occurs in the area between lat. 33°N and lat. 34°N (Howell et al., 2008), while the economic return per unit of effort is highest in the area near lat. 32°N. As a result, the trade-off value would be relatively high in the area around lat. 33°N.

Trade-offs Before and After Regulations

The swordfish fishery reopened in 2004 with a set of regulations rep-

resenting several years of effort by NMFS, the Western Pacific Fishery Management Council, the fishing industry, and conservation groups, to reduce the level of sea turtle interactions. The regulations, including mandatory use of circle hooks (replacing J hooks), use of fish bait (replacing squid as bait), and other conservation measures led to a dramatic reduction in rates of fishery interaction with loggerhead and other turtle species. However, the monthly patterns (peak and nadir) of the loggerhead turtle interaction rates were similar between the earlier period of the fishery (1994–2001) and the 2004–06 regulatory regimes, shown in our GAM analysis. This implies that the seasonality of sea turtle interactions with the fishery was unchanged although the overall inter-

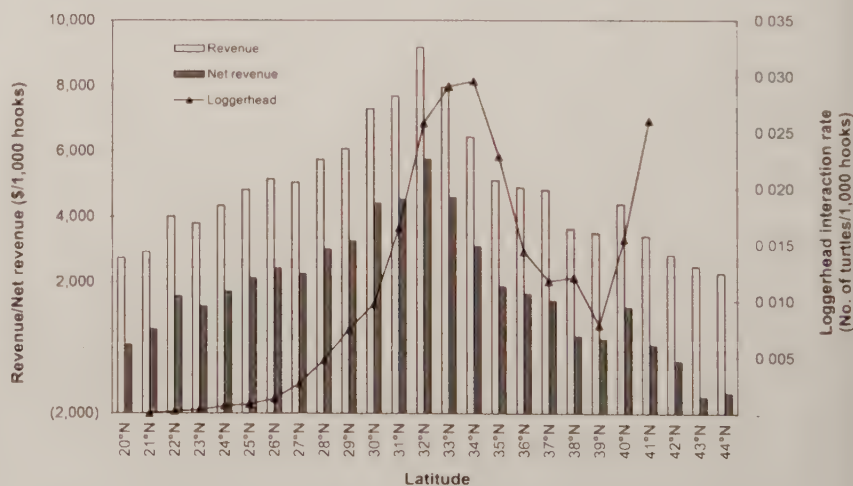


Figure 3.—Economic returns and loggerhead turtle interactions across latitudes.

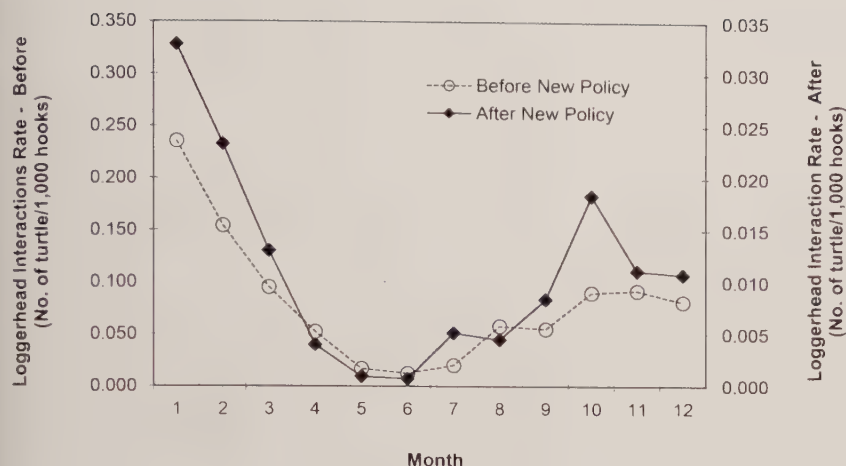


Figure 4.—Loggerhead interaction rates in the shallow-set swordfish longline fishery by month before (left y-axis) and after (right y-axis) new regulations were implemented in 2004 (note that left y-axis scale is 10× right y-axis scale).

action rate declined due to the new regulations.

Figure 4 illustrates the loggerhead interactions across months. For both before and after the new regulations, the loggerhead catch rate was the highest in the first quarter and lowest in the middle of the year (May, June, and July). However, the average monthly interaction rates of loggerhead turtles during 2004–06, 0.0111 per 1,000 hooks, were approximately eight times lower than the average monthly interaction rates from 1994 to 2001, 0.0804 per 1,000 hooks. Note that the scales of the two y-axes in Figure 4 are of much different magnitudes before and after the new policy regulations.

While sea turtle interactions declined, the catch rates of targeted fish species showed no significant changes under the new regulations. As a result, the magnitude of the trade-offs between loggerhead interactions and economic returns changed. During the 1994–2003 period, the swordfish fishery interacted with one loggerhead turtle for every 23,000 lb of swordfish caught, valued at \$49,000 (nominal ex-vessel swordfish revenue). After the adoption of the new regulations on gear and bait (2004–06), the fishery interacted with one loggerhead turtle for every 238,000 lb of sword-

fish caught (\$505,000 nominal ex-vessel swordfish revenue). Thus, under the lower interaction rate after the 2004 regulations, harvesting the same amount of swordfish may only interact with one-tenth of the sea turtle interactions that occurred in the period prior to the regulations.

On the other hand, to save one additional turtle (such as by imposing a more restricted sea turtle cap), it may cause ten times more foregone revenue of the swordfish fishery, since the marginal cost to the fishery for saving an additional sea turtle was much higher after the policy, when the sea turtle interaction rate was low.

Trade-offs and Fishermen's Behaviors

Fishing behavior in the swordfish fleet, such as fishing locations and fishing effort distribution among seasons, changes from year to year. Such changes can lead to substantial differences in the total number of sea turtle interactions, even at a fixed level of annual fishing effort. In the Hawaii swordfish longline fishery, if fishing effort is more concentrated in the first quarter, the risk of reaching the loggerhead sea turtle interaction cap is much higher than if fishing effort is more evenly distributed over the year.

For example, in 2006, the Hawaii-based longline swordfish fishery reached the cap of 17 loggerhead turtle captures within the first 3 months of the fishing season, with only 850 shallow sets. This led to a sudden closure of the fishery for the rest of that year. However in the prior year, 2005, the fishery caught only 12 loggerheads with 1,639 shallow sets, and the fishery remained open for the entire year. The number of fishing sets in the first quarter of 2006 was 55% higher than in 2005, which might directly contribute to more turtle interactions in 2006 since there was no significant difference in loggerhead turtle interaction rates between the first quarters of 2005 and 2006 (Gilman et al., 2006).

We predicted sea turtle interactions under several scenarios given a fixed fishing effort level but with different seasonal patterns. Historically, the seasonal patterns of the swordfish fishery have been rather variable. Different patterns of fishing effort can be assumed to reflect possible fishing behaviors of the fleet, and under each effort pattern the model can be used to predict the upper and lower bounds of sea turtle interaction with a specific fixed level of effort. Results of the model analysis could allow decision makers to evaluate the effectiveness of the fishing effort limits when no direct control is placed on the behavior of the fishermen (e.g., their seasonal fishing effort distribution).

Assuming an annual fishing effort limit of 2,120 shallow fishing sets and the loggerhead interaction cap of 17 turtles, this study evaluated various effort allocations across months (fishing behaviors) to estimate the impact on sea turtle takes and economic returns. The effort distributions studied included: 1) monthly allocation based on the historical (1994–2006) average pattern, and 2) the actual fishing effort pattern by month based on a particular year (e.g., 1994 or 2000). Results of the analysis are presented in Table 2.

The results indicate that fishing effort distributions across months lead to substantial differences in the trade-offs between sea turtle interactions

Table 2. – Predicted sea turtle interactions and economic returns under different fishing behaviors.

Fishing effort allocations ¹	Month	Monthly sets	Monthly cumulative sets	Cumulative loggerhead interactions	loggerhead net revenue ² (\$1,000)
Historical pattern (1994–2006 avg)	1	157	157	4	\$595
	2	161	318	7	\$1,290
	3	251	569	10	\$2,102
	4	267	836	11	\$2,733
	5	259	1,095	11	\$3,056
	6	243	1,338	11	\$3,614
	7	212	1,550	12	\$3,970
	8	137	1,687	13	\$4,072
	9	94	1,781	13	\$4,184
	10	119	1,900	15	\$4,254
	11	100	2,000	16	\$4,384
	12	120	2,120	17	\$4,548
1994	1	563	563	15	\$2,132
	2	429	992	23	\$3,985
	3	644	1,636	30	\$6,070
	4	484	2,120	31	\$7,212
2000	1	215	215	6	\$814
	2	299	514	11	\$2,106
	3	518	1,032	17	\$3,782
	4	623	1,655	19	\$5,253
	5	465	2,120	19	\$5,833
2006 (actual)	1	284	284	5	\$1,076
	2	327	611	8	\$2,488
	3	328	939	17 ³	\$3,550
	4	0	939	17	\$3,550
	5	0	939	17	\$3,550

¹Allocations of monthly swordfish fishing effort follow the monthly pattern of shallow sets each year.

²Calculation of net revenue is based on monthly fishing effort (sets), and spatial and monthly net revenue (2005 values) per shallow fishing set from 1994 to 2006.

³The total loggerhead turtle catch reported here includes two unknown hardshell turtles. Data source: National Marine Fisheries Service (NMFS) Pacific Islands Region Observer Program.

and economic returns even though total fishing effort is constant. For example, if fishermen fished the same seasonal pattern as the historical average, their fishing effort would be fairly evenly distributed across the months with a slightly higher level in the second quarter and lower level in the first quarter. Under this scenario with an effort limit of 2,120 sets, the estimated number of loggerhead sea turtle interactions would be near 17 and the fleet-wide net revenue would be approximately \$4.5 million. Applying the fishing effort distribution pattern observed in 2005, the model predicted the number of loggerhead sea turtle interactions as approximately 17 with an effort of 2,120 sets.⁵

In contrast, if fishermen behaved according to the 1994 monthly fishing effort pattern (with substantially more effort in the early months), the 2,120 effort limit would be exceeded in April. Given the concentration of fish-

ing effort in these months, particularly in January, more interactions would be expected to occur, and the fishery probably would close early with sea turtle interactions reaching their limit (17 interactions) in February. Similarly, if fishermen followed the fishing effort pattern observed in 2000, the cap of sea turtle interactions would likely be reached by March. Therefore, if fishing effort is intensively applied during the first quarter, the risk of loggerhead sea turtle interactions reaching the cap would be high, with the result that shallow-set operations would be halted. For the remainder of the year, further long-line fishing would be restricted to targeting tuna using deep-set gear. This situation actually occurred in 2006. During the first quarter of the year, fishing effort was highly concentrated and the accumulated number of loggerhead sea turtle interactions reached to 17 on 17 March 2006. As a result, the swordfish fishery was closed for the remainder of the year.

The model simulations and results discussed above illustrated the various

trade-off relationships involved in fishery operations. Based on the information, we may design different policy options to search for an optimal solution for the two conflicting management goals.

Policy Design and Implication

Previously, the lack of seasonal and area specific information on the trade-offs between sea turtle interactions and economic returns made it difficult to determine optimal time and area closures (WPRFMC, 2009). The model we developed in this study can be used to analyze the impacts of management policy options, including seasonal and spatial closures. In particular, the model can be used to examine swordfish fishing opportunities under various time-area closures, given the constraint of the sea turtle interaction cap. For example, we evaluated a trio of hypothetical area closures in which fishing was prohibited northward of lat. 32°N, 31°N, or 30°N. Figure 5 shows the results of these three hypothetical area closures and the baseline scenario (no area closure). In the analysis, we assumed that fishermen allocated their swordfish fishing effort in the first 4 months of the year, as in 1994 (Table 3 shows the monthly effort distribution) when the unit economic returns are high. Without any area closure, application of the entire 2,120 monthly cumulative sets was predicted to result in 31 interactions with loggerhead turtles and net revenue of \$7.212 million.

However, given the interaction cap of 17 turtles, this alternative is not feasible; the swordfish fishery would be terminated in February after achieving a net return of less than \$3.0 million, and the vessels would have to turn to tuna fishing using deep-set gear. Similarly, closure of the area north of lat. 32°N might reduce the number of turtle interactions by 3, but the risk of exceeding the cap would still be high; the expected number of interactions would be 28 loggerhead turtles and, given the cap, the fishery would likely be closed early in the year.

In contrast to these two scenarios, the closure of waters north of lat.

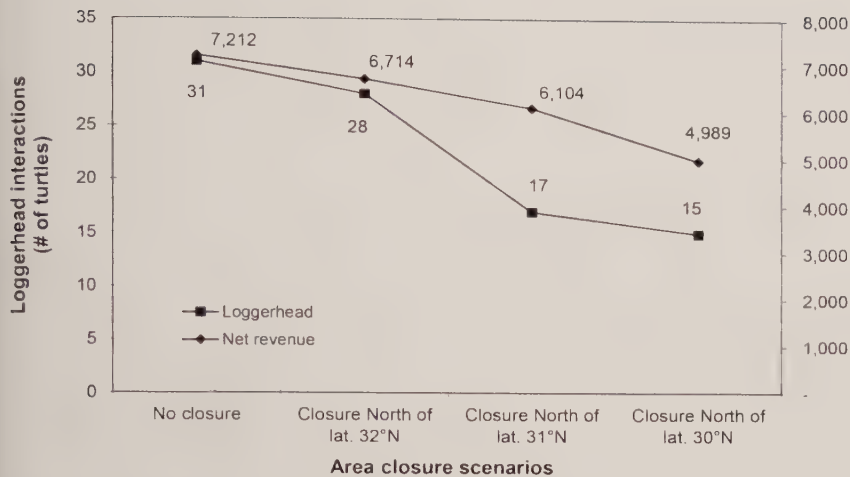


Figure 5.—Results of the hypothetical area closures and no area closure.

31°N would lead to many fewer turtle interactions. In this scenario, the predicted loggerhead interactions would not exceed the cap (17 loggerheads), and a net economic return of \$6.104 million would be predicted, the highest net revenue the swordfish fleet could achieve, based on shallow-set operations, among the scenarios of area closure analysis presented in the graph (Fig. 5). From this area-closure-scenarios analyses, the average cost of reducing interactions of the swordfish fishery with sea turtles from 31 to 17 is \$79,000 in net revenue (\$101,000 in gross revenue) per sea turtle.

A previous study by Curtis and Hicks (2000) estimated the average cost of reducing interactions of the swordfish fishery with sea turtles before the new regulations was \$41,262 per turtle. The figure estimated in this study was 2.5 times higher than the Curtis and Hicks (2000) report. Again, it shows that when the sea turtle interaction rate was lower, the average cost

of further reducing interactions with sea turtles through partial area closure would be higher.

The limitation of swordfish fishing to waters south of lat. 31°N in this scenario corresponds roughly to similar advice given to fishermen to reduce interactions with loggerhead sea turtles by the NMFS TurtleWatch Program (Howell et al., 2008), which generates maps of sea surface temperature in the Hawaii longline swordfish fishing grounds and delineates areas where interactions with sea turtles are considered most likely to occur. The experimental maps are regularly posted online.⁶

Based on accumulated knowledge that loggerhead turtles prefer to stay in water colder than 65.5°F (about 18.5°C), the TurtleWatch maps delineate this boundary and advise longline fishermen to avoid fishing in waters colder than 65.5°F. During the first

⁶<http://www.pifsc.noaa.gov/eod/turtlewatch.php>.

quarter of the year, the 65.5°F isotherm lies approximately along lat. 31°N. Thus if swordfish fishermen adhered to the TurtleWatch advice (effectively a voluntary area closure), the model predicts they would achieve \$6.104 million net revenue while not exceeding the cap of 17 loggerhead sea turtle interactions.

In addition, results from the area-closure-scenarios shown in Figure 5 show that the cost of reducing interactions with sea turtles varied by the number of sea turtles that policy makers aim for as a limit. For example, if policy makers want to reduce the interaction with sea turtles from 31 to 15 (instead of the cap of 17 sea turtles in effect), the average cost would rise to \$139,000 per turtle in net revenue (\$156,000 in gross revenue), a 76% increase in cost to the fishery compared to the limit of 17 sea turtles. The unit cost increases dramatically if the policy makers aim for less than 15 sea turtle interactions.

Besides examining hypothetical area closures, the study evaluated the policy option of closing the swordfish fishery during months when high sea turtle interaction rates are expected. For example, a seasonal closure for the first 3 months could significantly reduce the risk of exceeding the sea turtle cap for the remainder of the year. Such a seasonal closure would limit fishing to months of lower sea turtle interaction rates and lower economic returns; however, it would extend the swordfish fishing season and allow the opportunity to fully use the fishing effort limit. Table 3 shows the results of a hypothetical seasonal closure in January. The single-month January closure may lead to a significant reduction in sea turtle interactions. Compared to the baseline scenario of no closure, the model predicted the number of loggerhead interactions could be reduced from 31 to 18, just slightly exceeding the cap.

The model demonstrated that there may be policy alternatives, either seasonal closures or area closures, that could have achieved higher economic returns than the actual industry performances in 2005 and 2006. Table 4

Table 3.—Predicted loggerhead sea turtle interactions and economic returns under a seasonal closure alternative.

Fishing effort allocation pattern	Month	Monthly sets	Monthly cumulative sets	Cumulative loggerhead interactions	Cumulative net revenue ¹ (\$1,000)
1994	1	0	0	0	\$0
	2	429	429	8	\$1,853
	3	644	1,073	15	\$3,937
	4	743	1,816	17	\$5,691
	5	304	2,120	18	\$6,071

¹Calculations of net revenue are based on monthly fishing effort (sets) and spatial and monthly revenues (2005 value) from swordfish fishing (effort unit measured by sets) from 1994 to 2006.

Table 4.—Predicted economic returns and number of loggerhead interactions under various scenarios and the actual economic returns of the industry in 2005 and 2006.

Scenarios or actual events	Fishing effort (sets) ¹	Loggerhead turtle interactions	Revenue (\$ million)	Net revenue (\$ million)
Actual industry performance				
2005	1,604	12	7.80	3.97
2006	939	17	5.86	3.55
Analysis alternatives				
1. Historical average (Table 2)	2,120	17	9.56	4.55
2. Seasonal closure (Table 3)	1,816	17	9.96	5.69
3. Area closure ² (Fig. 5)	2,120	17	11.00	6.10
4. Area closure ³	2,120	17	11.32	6.40

¹The official PIFSC figure for shallow sets actually made in 2005 was 1,645 sets and in 2006 was 850 sets based on the landing data. The 1,604 and 939 figures in the table are PIRO's number of shallow sets made by vessels based on departure in 2005 and 2006, respectively. The study used the PIRO definition to count sets.

²North of lat. 31°N.

³East of long. 166°W and north of lat. 31°N.

presents a summary of the estimated economic returns that might be realized from four hypothetical policy alternatives and the actual industry performances in 2005 and 2006. All four of the scenarios (three have been discussed above) result in a predicted net revenue (and gross revenue) higher than the estimated net revenue obtained by the industry in 2005 and 2006, while not exceeding the loggerhead sea turtle interaction cap (17 turtles).

As noted above, under an area closure north of lat. 31°N, the third scenario in Table 4, the industry might harvest \$11 million worth of swordfish and earn approximately \$6.104 million net revenue. If the closed area was reduced by closing only the area east of long. 166°W and north of lat. 31°N, as in the fourth scenario, the industry would be expected to achieve about \$11.32 million revenue or \$6.40 million net revenue. The predicted net revenue under this scenario is approximately \$3 million higher than the net revenue in 2006 (although this calculation does not account for the revenue gained by these vessels as they fish for tuna with deep-set gear during the swordfish fishery closure for the rest of the year).

Conclusions

Conservation measures have resulted in a dramatic reduction of sea tur-

tle interactions in the Hawaii-based longline fishery for swordfish. However, annual caps on loggerhead turtle interactions resulted in foregone fishing opportunity and created uncertainty for participants in the fishery owing to possible fishery closures.

This study explored the trade-offs between the risk of sea turtle interactions and the economic returns from swordfish fishing, and identified examples of alternative management options that could allow the swordfish fishery to operate throughout the year with a reduced risk of exceeding the cap on loggerhead sea turtle interactions. The study suggests that carefully designed area closures or seasonal closures confining fishing effort to areas and/or months with lower likelihood of interactions, would be one way to reduce the risk of the fishery reaching the sea turtle cap early in the fishing season and thus enable the industry to achieve higher annual economic returns. The study demonstrated that a bioeconomic model integrating information on fishery dynamics and net revenue can be a useful tool for fishery management decision making.

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Limited-access Privilege Programs in the Mid-Atlantic Fisheries

BARBARA P. ROUNTREE

Introduction

A catch share program is a generic term associated with fishery management strategies that allocate a specific percentage of the fishery catch to individuals, cooperatives, communities, or other entities. It includes more specific programs such as Limited Access Privilege Programs (LAPP's).

The Fishery Conservation and Management Act of 1976 (later renamed Magnuson Fishery Conservation and Management Act and then Magnuson-Stevens Fishery Conservation and Management Act) created a new national program for the conservation and management of marine fishery resources. Fishery Management Plans (FMP's) were to be developed by eight regional fishery management councils and implemented by NMFS.

In 2006, Magnuson-Stevens Fishery Conservation and Management Reauthorization Act (hereafter referred to as the Reauthorization Act), urged regional councils to use more LAPP's in federal fisheries management (NMFS, 2007). LAPP's had also been speci-

fied as a priority in the U.S. Ocean Action Plan¹ and Executive Order 12866, signed by President William J. Clinton in 1993, which established the guiding principles agencies must follow when developing regulations.

In 2005, under President George W. Bush, NMFS pledged to double the number of fisheries managed under LAPP's (from 8 to 16) by 2010. In 2010, the Obama administration solidified its commitment to catch shares by issuing a Catch Share Policy (NOAA, 2010) to provide guidance and support on the design, implementation, and monitoring of catch share programs. This policy provides a foundation for facilitating the widespread consideration of catch share fishery management plans (FMP's) while enabling local fishermen and communities to be part of the process.

This article explains what LAPP's are, how they work, and what benefits and costs can be expected from their implementation. First, a brief history of fisheries management helps explain how LAPP's evolved. This is followed by an explanation of the economic incentives behind LAPP's, in the context of two fisheries in the U.S. Mid-At-

lantic Region—the Atlantic surfclam/ocean quahog, *Spisula solidissima*/*Arctica islandica*, fishery and the tilefish (also known as the golden tilefish), *Lopholatilus chamaeleonticeps*, fishery.

Limited-Access Privilege Programs

Prior to 1976, U.S. marine fisheries were managed in a completely open-access environment, with few restrictions placed on foreign or domestic fishermen or their activities. Competition among fishermen under open-access conditions creates incentives for the industry to expand, over-exploit, and eventually deplete the resource (as described by the popular phrase “tragedy of the commons”), resulting in overcapacity and overfishing (Anderson and Holliday, 2007).

With the passage of the Fishery Conservation and Management Act of 1976, fisheries management began to evolve, using various combinations of input and output controls. Input controls were put in place to restrict vessel activity in various manners, by regulating the type and/or amount of gear, or by restricting fishing areas or fishing times.

Output controls were also established that aimed to limit the amount of catch or harvest in a fishery, such as limits on a total allowable catch (TAC) or individual trip catch. These too had a downside. A hard TAC (a predetermined catch level that is paired with a within-season closure provision) implemented for a fishery as a whole often leads to heightened competition to catch as much fish as possible before the annual limit is reached; a “derby fishery” in which there is a “race to fish.” Gear restrictions and trip limits

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ABSTRACT—The use of limited-access privilege programs (LAPP's) in fisheries management offers an incentive for collaborative management while also addressing economic incentives. This paper provides an overview of the development and use of limited access privilege programs by looking at a review of potential benefits and the arguments against them. It focuses on examining

the historical context of two specific applications in the Mid-Atlantic—the Atlantic surfclam, *Spisula solidissima*, and ocean quahog, *Arctica islandica*, fishery, and the tilefish, *Lopholatilus chamaeleonticeps*, fishery. Structural components of these programs are presented along with a description of notable changes in these two fisheries since the implementation of LAPP's.

¹The plan, subtitled The Bush Administration's Response to the U.S. Commission on Ocean Policy, is available online at http://www.cmts.gov/downloads/US_ocean_action_plan.pdf.

can lose their effectiveness through technological improvements, and with both output and input controls, there are no incentives for fishermen to delay or abstain from fishing, because “any fish not caught is likely to be taken by someone else” (Anderson and Holliday, 2007).

Councils then turned to limited-access programs, initially with no additional controls. Unfortunately, simply limiting the number of participants (frequently too late for the stock to recover) was not enough to eliminate the race to fish among those allowed in the fishery. Fishermen upgrade vessels, adapt to new technologies, and increase trip length, until very short seasons result.

Acknowledging the failures with traditional open-access and limited-access approaches, managers have looked toward LAPP's², in which individuals are granted the privilege to catch a specified portion of a science-based TAC. The idea behind a rights- or market-based approach is to mimic the characteristics of a property right. One of the central arguments in favor of this approach is that this sets up an efficient market where costs are minimized and economic benefits maximized.

Under this type of access control, the vessel-level incentives are to catch the complete owned share of the TAC at the lowest cost possible and to sell at the highest possible price. According to the Reauthorization Act, limited access privilege programs encompass a range of privileges assigned to entities constituted either by individuals (i.e., individual fishing quotas) or groups (e.g., corporations, cooperatives, and area-based groups).

The total annual harvest quota (or total allowable catch) for a species is divided into quota shares that are then assigned to eligible entities. By using a broad definition of entity, more options are available for the councils to consider. Not every entity in the fish-

ery at the time a LAPP is designed necessarily receives a share, and some entities receive much larger shares than others. The size of the share can be based on landings in specific years (entities with higher landings receiving larger shares) or on many other factors. Each entity's quota represents the right or privilege to harvest a quantity of fish, usually expressed as a percentage of a fishery's TAC.

The primary goal in using a LAPP is to correct for the problems resulting from incentives provided by regulated open-access regimes. Without strong enforcement of the TAC, the race to fish and the desire to get around regulations may lead to low stocks and fleets with larger capacity than necessary. A LAPP, on the other hand, creates incentives to harvest quota shares as efficiently as possible and to process the catch to maximize the quota share's net value to the entity.

One of the key elements of a LAPP is a scientifically determined, fully enforced constraint on the total number of fish caught and landed. Fleet-level benefits may include the efficiency gain in production from fishing capacity reductions; greater rewards for conservation, and stewardship; reduced bycatch (when there is adequate monitoring); and more efficient use of fish products by processors.

When instituted in a derby fishery, a LAPP ends the incentives to race to catch fish. Vessel owners can plan to harvest their quota at any time throughout the year, resulting in safer working conditions and higher-quality products, as well as more flexibility in adjusting to regulations and the ability to participate in other fisheries during appropriate seasons. This leads to more economic certainty for fishermen and a more stable supply of fish.

Supply disruptions are reduced or eliminated when fishermen are no longer faced with closures imposed to prevent an allocated seasonal quota from being exceeded. The incentives under a LAPP tend to maximize the difference between the value of the harvest and the costs of catching those

fish, both for the individual entity and from a national perspective.

A LAPP often allows a quota holder to transfer the harvest privilege, by sale, lease, or other method, to another entity. Such transfers allow for long-term planning and may be expected to reduce the number of firms or fishermen and vessels, and consolidate the quota among the more efficient fishermen, subject to limits on excessive accumulation of shares. Leasing (or the transfer of the annual harvest privilege) allows short-term flexibility to change vessel behavior in response to outside factors.

Unrestricted quota trading promotes economic efficiency, because those willing to pay the highest price for quota would be those expected to use them the most profitably, by catching fish at a lower cost or transforming the fish into a more valuable product (GAO, 2004). Transferability is crucial to letting the market allocate scarce resources in an efficient manner. Transferability allows shares to acquire value as assets, regardless of whether the holder earns income from fishing. Lastly, those wishing to leave the fishery receive compensation for their shares, not simply for the vessel and equipment remaining after a career in an open-access fishery.

To address the initial challenges in designing LAPP's, the NMFS Office of Policy directed the development of a document on LAPP's informed by a steering committee comprised of NOAA, FMC's, and other personnel experienced with such programs (Anderson and Holliday, 2007). The guidelines evaluate “the relative pros and cons of various approaches and address general questions about the future use” (Anderson and Holliday, 2007:iii) of LAPP's given past experience with domestic and international programs. Since then, NOAA's Catch Share Policy (2010) further refines a series of guiding principles to follow to ensure the best catch share design, implementation, and outcomes.

These principles include the thorough examination of specific management goals, initial share allocation,

²These have in the past been variously referred to as individual transferable quotas (ITQ's), individual quotas (IQ's), individual fishing quotas (IFQ's), community quotas, etc.

transferability of share, duration, recovery of program cost from its participants, review process, eligibility criteria, and share accumulation. The two LAPP programs described here were designed separately by the Mid-Atlantic Fisheries Management Council (MAFMC), with differing approaches to the set of guiding principles. Not surprisingly, in the design of LAPP's, there are many components to consider which may/may not benefit participants and depend on the specifics of the particular fishery. Some of the more controversial individual criteria will be addressed later for a specific fishery.

There have been ongoing debates about both the effectiveness and the limitations of catch shares as a fisheries management tool. Critics point to some potential drawbacks of LAPP's. The most difficult task in implementing LAPP's involves the allocation of initial quota shares. The Reauthorization Act emphasizes that initial allocations must be "fair and equitable" and consider "current and historical harvests, dependence upon the fishery," and "the current and historical participation of fishing communities" (NMFS, 2007:83). These phrases can be subject to various interpretations and highlight the difficult nature of the decision.

Other factors that may cause concern include the possible concentration of wealth in the hands of a few, monopolization, concerns about equity among vessel size classes and communities, and the need for careful monitoring. The Reauthorization Act requires the establishment of limits on acquisition of excessive shares and consideration of small vessels and their crew members. LAPP's create incentives to reduce labor and capital inputs. In so doing, they may cause social disruption during their implementation, as allocations favor some and disfavor others, and while excess harvesting capacity is retired or moved into other fisheries, and processing capacity switches to different products or product forms.

Critics also argue that LAPP's allo-

cate public resource rights to private citizens and that they reduce fishermen's access to a public resource. The NMFS guidelines (NOAA, 2010) suggest that these programs can create privileges with characteristics that provide many of the same positive incentives as traditional property rights. These critical characteristics of property rights include exclusivity (degree of control over right), permanence (duration of the right), security of the right, divisibility, and the transferability of the right (Anderson and Holli-day, 2007).

In effect, fish stocks are a publicly owned resource managed by LAPP's. This suggests that the property rights are not to the resource, but to the harvesting of a specified annual amount of the resource. The fish are private property after they are brought on board a vessel. In fact, the Reauthorization Act explicitly states that a LAPP is a permit that can be "revoked, limited, or modified at any time" and does not "confer any right of compensation to the holder" under those circumstance (NMFS, 2007:79).

Apprehension exists in the minds of many people about the potential costs of LAPP's, for example preventing new fishermen from entering the fishery, disruption of fishing communities, and eliminating fishing traditions. Fishery managers face the inherent tension between the economic goal of maximizing efficiency and the social goal of protecting communities or facilitating new entry (GAO, 2004).

In New England, a region adjacent to the Mid-Atlantic Region, managers have instituted an alternative to LAPP's: giving the harvest privilege, or allocation of catch shares, to sectors or subsets of the fleet. A sector, in this context, is a group of persons holding limited access vessel permits who have voluntarily entered into a contract and agreed to certain restrictions for some period and who, as a group, have been granted a TAC.

The contract is used to implement rules that govern harvest of the sector allocation. The fishermen within the sector allocate harvest shares

among themselves and may carry out other functions as well. The allocation to sectors is based on fishing harvests over an agreed-upon set of years. Whereas an individual harvest percentage is calculated for all qualified vessels, only those vessels that are members of a sector can take possession of a sector's share. Non-sector vessels continue to fish in the competitive common pool fishery.

A comparative study on the uses of individual fishing quotas vs. sectors concluded that a combination of the two approaches may work better than either technique alone (GAO, 2004). In general, deciding who should receive a quota and how much they should receive is a controversial and highly political process. In some cases, for example, in the mid-1980's between commercial and recreational Coho salmon, *Oncorhynchus kisutch*, in Oregon, an independent allocation panel, comprised of people from both interest groups, worked well in providing allocation decisions with long-lasting satisfaction (Morrison and Scott, 2014). Additionally, the use of sectors in the U.S. Northeast provides an alternative that keeps this allocation decision outside of the hands of government.

LAPP's in the Mid-Atlantic Region

The Atlantic surfclam/ocean quahog and tilefish fisheries in the Mid-Atlantic region have long benefitted from the fishermen's active involvement in the management process. In addition, both fisheries have characteristics that make them ideal candidates for LAPP's. Positive factors in the case of surfclam/ocean quahog include the lack of substitutes, the small geographic range of the bivalves, manageable number of vessels, small number of landing ports, good historical catch records, no recreational component, and a highly specialized gear type have helped make it a clean (i.e., low bycatch) fishery (NRC, 1999).

Several features of the tilefish fishery also make it an ideal case for LAPP (in this case, individual fishing quotas (IFQ)) management: the geo-

graphic range is restricted to a narrow band of ocean bottom along the outer continental shelf and upper continental slope, the numbers of vessels and vessel owners are very small, the number of landing sites is limited, it is a relatively clean fishery, and a recreational component, though growing, is not significant.

The Atlantic Surfclam/Ocean Quahog Fishery

The surfclam and ocean quahog (SCOQ) fishery off the U.S. Atlantic coast has a considerable history going back at least to the 1960's (Kulka, 2011). It follows quite closely the simplified history of rights-based fisheries management previously described. Demand for commercially harvested surfclams increased markedly in the early 1970's. As surfclams came to represent almost 75% of the U.S. clam market, they became subject to very heavy fishing pressure.

The ocean quahog fishery arose as a substitute when the Atlantic surfclam fishery began to decline in the mid-1970's. While ocean quahogs are found farther off-shore, many of the same vessels are used in both fisheries. The Atlantic surfclam/ocean quahog fishery was the first to be managed under the Magnuson-Stevens Act in 1977, becoming the first limited-access fishery in the U.S. Exclusive Economic Zone (EEZ) established by that legislation. Even though initially the total number of vessels was fixed, total fleet capacity was allowed to expand because there were no constraints placed on vessel size or gear technology. The classic race to fish continued, prompted by drastic declines in the number and length of trips allowed to permitted vessels.

The Mid-Atlantic Fishery Management Council (under Amendment 8 to the Fishery Management Plan for the Atlantic Surfclam and Ocean Quahog Fisheries) established individual transferable quotas (ITQ's) in 1990 (MAFMC, 1988). Access under Amendment 8 was limited to those who owned a vessel that was either fishing in 1978 or being built in 1977.

The Reauthorization Act was designed with specific objectives to protect fishing communities while facilitating some new entry.

In contrast, the Atlantic surfclam/ocean quahog ITQ program was designed simply to help stabilize the fishery and reduce excessive investment in fishing capacity. Eighty percent of the initial allocation of Atlantic surfclam quota shares was based on vessel catch history from 1979 through 1988, with the remaining 20% based on vessel capacity. Ocean quahog shares were based solely on landings history. Amendment 8 included no specific and measurable limits on how much quota an individual could accumulate. Quota could be sold and leased which provided entry opportunities into the fishery.

There were few constraints on ownership eligibility, transfer, and other features. Shortly after implementation, the buying and selling of quota yielded quickly to a market based primarily on leasing. Some of the firms gave up harvesting in favor of generating income through leasing their quota to other harvesters. This created a unique situation where it is no longer necessary or perhaps desirable to own a vessel in order to own some quota. There are various types of ITQ transactions that occur frequently, including permanent transfers or sales, relatively long-term leases (e.g., five or more years), and transfers of bushel tags.

Concentration and Market Power

Under the ITQ system, increased concentration of shares in the hands of one or a few entities can be a concern to policymakers, providing companies with market power and enabling them to influence prices in input and output markets. The Reauthorization Act (NMFS, 2007) states that ITQ privilege programs should ensure that limited access privilege holders do not acquire an excessive share of the total limited access privileges in the program. The National Standard 4 of the Reauthorization Act requires that fishing privilege allocations be carried out so that "no particular individual, cor-

poration, or other entity acquires an excessive share of such privileges."

The current level of concentration in the industry can be measured by the Herfindahl-Hirschmann index (HHI) (Hirschman, 1945; Herfindahl³). According to U.S. government Horizontal Merger Guidelines. (USDOJ and FTC, 2010), agencies generally classify markets into three types: "Unconcentrated Markets" (HHI below 1500), "Moderately Concentrated Markets" (HHI between 1500 and 2500), and "Highly Concentrated Markets (HHI above 2500).

Since it was not entirely clear what constitutes an "excessive share" in this context, a technical group of experts was asked to give independent advice on determining how to set an "excessive share" limit in any ITQ fishery and, in particular, for the SCOQ fishery (Mitchell et al., 2011).

As can be identified by a quick look at the data, concentration has occurred in the fishery with respect to the number of active fishing vessels and the number of processing companies. There also seems to have been a certain concentration in quota ownership although, apparently, to a lesser degree (Mitchell et al., 2011; NMFS, 2010). The Technical Group Report (Mitchell et al., 2011), states the number of processing plants was reduced from 44 in 1979 to 12 in 2011. In terms of purchases, the HHI for surfclams grew from 2,068 in 2003 to 3,134 in 2008, and, for ocean quahogs, from 3,431 to 4,369. Similar statistics for the development of concentration in quota holdings and harvesting are not available. However, in 2009, the combined (both species) HHI for quota holdings was 993 and for the harvesting activity was 2,890 (Mitchell et al., 2011).

Mitchell et al. (2011) addresses the question of whether market power can be exercised in this fishery through the ownership and withholding of quota. The exercise of market power in an ITQ-regulated fishery can occur when a quota owner has the ability and the

³Herfindahl, O. 1950. Concentration in the U.S. steel industry. Unpubl. Ph.D. dissert., Columbia Univ., N.Y.

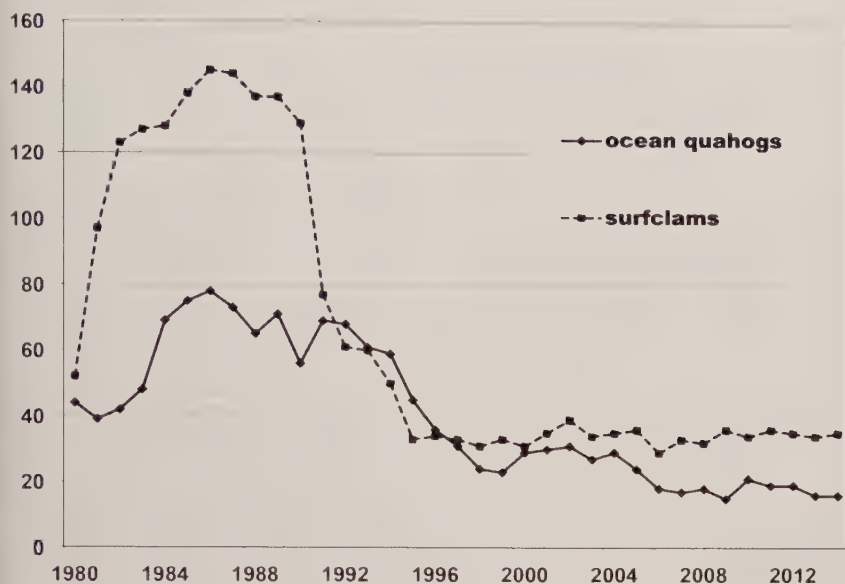


Figure 1.—Number of vessels in the surfclam and ocean quahog fisheries in the U.S. Exclusive Economic Zone, 1980–2014.

Individual firms should have no control over prices when other firms sell identical or nearly identical products. Due to the complexity of ITQ fisheries (quota holdings, quota trading, and the dynamic nature of the fishery), the determination of market power in an ITQ fishery is much more involved than for standard industries. In the SCOQ fishery, the main participants are 1) quota holders, 2) fishing companies, and 3) processing companies. Further, processors and wholesale distributors may also play a role in exerting market power on the harvesting sector. Some companies may be involved as one or more of these basic participants.

Some processors have developed quota ownership through either the acquisition of vessels and the accompanying quota or the acquisition of quota directly, and it is common for processors to enter into long-term contracts to lease quota from quota holders. Virtually all clams are sold under contract between processors and harvesters or are harvested by processor-affiliated vessels.

Having recognized the need for better transparency and having heard the advice from the CIE review, NMFS implemented additional data collection on ITQ allocation ownership and control for the surfclam and ocean quahog fishery in 2015. Its goal is to better identify the specific individuals who hold or control ITQ allocation in these fisheries, providing additional detail that the Council may utilize when developing an excessive shares cap.

Management

The Atlantic surfclam fishery is a good example of the success of fisheries management in terms of maintaining or restoring stocks. Since the implementation of ITQ's, the goal of consolidation and reduction of capacity in the fishery has been attained (Fig. 1). The number of vessels was initially quite high, because of grandfathered vessels when the moratorium was established.

Initially, no one wanted to exit the fishery because they knew their share would soon have value. The value of

incentive to affect the price of the regulated harvest or of the quota through its use or suppression of use of quota. The authors argue that the evidence does not support a conclusion that market power is being exercised. In particular, processors report that well before the end of the season, it is clear to them that excess quota will be available, leaving sufficient opportunity to continue to harvest if sufficient demand is shown, and leaving the price of quota low.

Using the Herfindahl-Hirschman index, it is found that the levels of concentration vary in the different sectors of the SCOQ industry: quota ownership, harvesting, and processing. The ownership of quota in the SCOQ fisheries is unconcentrated, but the use of quota is highly concentrated, for both harvesting and processing.

The advice from the technical group was evaluated further by the Center for Independent Experts (CIE), upon request by NMFS during a public review in June 2011 (Walden⁴). Unfortunately, given the complexity in

the subject, rather than one summary document, this resulted in individual reports submitted by the three CIE reviewers. They agreed that the HHI method is valid for measuring potential market power, but also that additional data is needed, as well as more transparency around ownership, transfers, and contracts for quotas. Studies need to be conducted to determine the appropriate mechanism for revealing quota prices in this fishery. The analysis was focused on the output markets as opposed to the input markets. Since this approach is applied to a vertically-integrated industry with a small number of processors and vessels predominantly controlled by the processors, the exercise of monopsony power (the ability of processors to exert market power on the harvesting sector) is of primary interest. Currently, eight processing firms purchase catch from the SCOQ fisheries.

In competition theory (Anderson and Holliday, 2007), market power refers to the company's ability to manipulate price to its benefit by influencing an item's supply, demand, or both.

⁴Walden J. 2011. Summary of findings by the Center for Independent Experts regarding setting excessive share limits for ITQ fisheries. U.S. Dep. Commer., Northeast Fish. Sci. Cent.

tradable ITQ's helps to explain the rapid consolidation that was able to take place after their introduction. The decline in the number of vessels was also due to market factors and use of larger and more efficient vessels. In 1990, 128 vessels participated in the U.S. EEZ fishery for surfclams; numbers declined to 75 in 1991, after implementation of ITQ management.

A significant portion of the reduction in active vessels was due to firms deciding to consolidate harvesting onto fewer of their own vessels. Profitability in the harvesting sector increased substantially (NRC, 1999). Within two years of implementation, the number of vessels harvesting surfclams in federal waters had been cut in half, and the average annual catch per boat doubled. Between 1995 and 2014, the number of vessels harvesting surfclams has varied somewhat, ranging between 29 and 43 vessels.

In recent years the combined harvest in federal waters has been almost 6 million bushels with a landed value between \$50 and 60 million (for 2014, \$30 million for surfclam and \$24 million for ocean quahog). Total landings (the amount of catch that is brought to port and sold to a federally permitted dealer) of both stocks from the EEZ have been less than the quota, due to market factors, especially in recent years (Fig. 2).

Beginning in 2005, a large percentage (between 33 and 45%) of ocean quahog allocation tags were allowed to expire, and the quota left unharvested. In contrast to the ocean quahog harvest, the surfclam fishery harvested almost all available quota each year beginning in 1980, until the last decade, when in some years, quota was left unharvested. Leaving quota unharvested is not an indication of poor management, but it is a factor of interest.

The number of ITQ allocation owners has also decreased from 154 in 1990 to 70 in 2014 for surfclams and from 117 to 41 for ocean quahogs over the same period. Originally, these allocations corresponded to the allocation shares given to each vessel owner

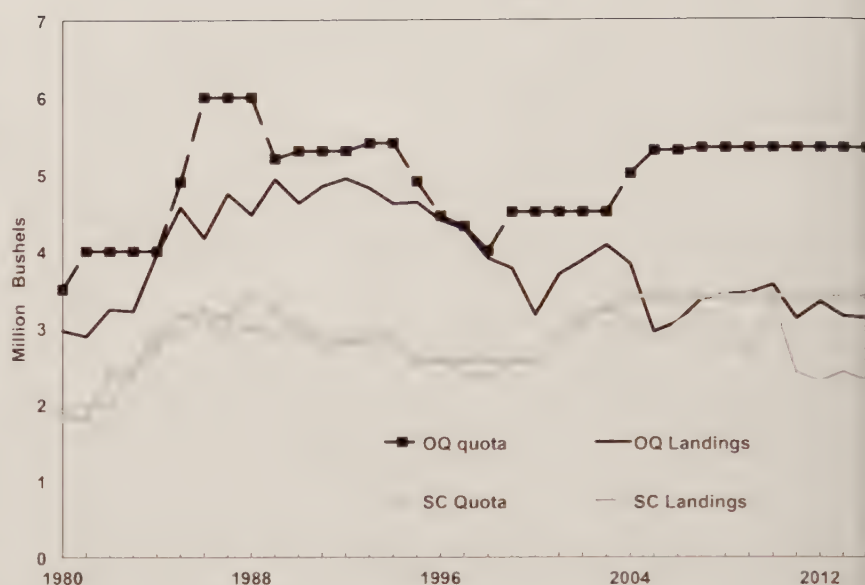


Figure 2.—Landings and quota for surfclams (SC) and ocean quahog (OQ) in the U.S. Exclusive Economic Zone, 1980–2014.

when the ITQ system was first implemented. Over time, they have been sold and combined with others, thereby reducing the number of allocation owners. A large number of allocation owners are either corporations or banking institutions holding the allocation permits in their names as collateral. A single individual could potentially own or control many of these individual share allocations. Similarly, a number of banks listed as allocation holders could have a single borrower under multiple loans. Because of these situations, policy makers have no ability to discern if a single individual is a shareholder in many of the corporations. Beginning in 2005, the industry experienced layoffs, especially among ocean quahog vessels. The difference between numbers of allocation holders and active vessels has narrowed, but it remains significant, especially among surfclam allocation holders, where 39 vessels were active out of 70 entities holding share for 2014 (Fig. 3).

The surfclam/ocean quahog fishery consists of a mixture of independent (owner/operator) fishermen, small processors, and a few large vertically integrated companies. After an extensive

study of the number of firms (rather than vessels), Brandt (2005) concluded that ITQ's in the clam fishery did not harm small fishermen or force them out of the fishery to the benefit of larger, vertically integrated processors, indicating that the decline in the number of vessels in the fishery masks the fact that far fewer firms left the industry.

The Tilefish Fishery

Beginning in the 1980's, there was recognition that the tilefish resource was over-exploited and that there was more capacity in the fishery than was needed. Many years later a limited-access system was established, primarily due to the participation and encouragement of active vessel owners. The tilefish FMP established (beginning 1 Nov. 2001) a total allowable landings (TAL) system as the primary control on fishing mortality (MAFMC, 2000). The FMP also implemented a limited-entry program and a tiered commercial quota allocation of the TAL. Each of three defined categories (full-time tier 1, full-time tier 2, and part-time vessels) is allocated a percentage of the overall TAL.



Figure 3.—Surfclam allocation holders and active vessels in the U.S. Exclusive Economic Zone, 1990–2014.

This particular quota management approach for tilefish has some unusual features. Beginning with the FMP, tier 1 members participated in group management and behaved as if they already had an IFQ (Kitts et al., 2007). The four tier 1 members have been able to cooperate because, after lobbying the Council during the management process to be in a separate permit category with their own group allocation, they divided the group TAC among themselves. More specifically, even though ITQ's were not yet implemented, under a cooperative understanding tier 1 participants have been coordinating their landings throughout the year and avoiding landing during the same time as participants in other categories. They received higher prices due to their coordinated behavior, something the members of other tiers now benefit from as well (Rountree et al., 2008).

Industry participants had been in favor of instituting IFQ's during the FMP design process, but were not able to follow through on the concept because of a moratorium that the U.S. Congress placed on instituting new rights-based programs from 1996 to 2002. After the ban was lifted, industry members encouraged the Council to reconsider so that tier 1 participants could codify their own agreement. This resulted in Amendment 1 to the tilefish FMP, which implement-

ed an individual fishing quota (IFQ), a traditional form of LAPP, for each of the three defined categories beginning 1 November 2009 (MAFMC, 2007). The IFQ program in the tilefish fishery simply regulates how catch is distributed among eligible vessel owners.

The requirement in the Reauthorization Act to consider "current and historical harvests" (NMFS, 2007:83) has particular relevance for the tilefish fishery. Historically, two distinct areas have been active in the fishery: one centered on Barnegat Light, N.J., and the other around Montauk, N.Y. The longline tilefish fishery was developed in New Jersey during the late 1970's, but by the 1980's, many of those vessels had diversified into other more economically viable fisheries.

An open-access commercial permit is available for commercial and incidental landings and charter party vessels. For any vessel to possess or land more than the incidental trip limit (currently 500 lb), the vessel must also fish under the authorization of an IFQ allocation permit. The IFQ allocation permit shall specify the quota share percentage held by the IFQ allocation permit holder and the total pounds of tilefish that the IFQ allocation permit holder is authorized to harvest.

Vessels with tilefish limited-access permits are still primarily from Bar-

negat Light (12 vessels), and Montauk (4 vessel permits with the largest recent landings). Many of the New Jersey tilefish vessel owners have now lost or severely lowered their claim to quota, given their landing history of diversification. Those who were not assigned an allocation of quota in Amendment 1 had ceased fishing for tilefish and had no recent landing history. However, all or part of the allocation specified in the IFQ allocation permit may be transferred on a temporary or permanent basis to any entity owning a documented vessel.

There were several IFQ alternatives considered in Amendment 1 to the tilefish FMP. They varied by degree of inclusion of all categories, and the means of allocating initial harvesting quotas or privileges. Expected disagreements on initial allocations focused on the choice between three proposed historical periods, as each fisherman favored their most active years in the fishery.

A compromise to a similar dilemma was reached in the wreckfish, *Polyprius americanus*, ITQ in the U.S. South Atlantic region, which allocated half of the available shares on an equal basis and half based on historical catch (Gauvin et al., 1994).

Tilefish prices have increased and been very strong since implementation of the IFQ program. A major reason for this is that the tilefish industry is able to coordinate times of landings to avoid market gluts and spread tilefish landings throughout the year. Prices vary by size, although all sizes are kept, since survival rates are low.

A rapid increase in the harvest of unregulated blueline tilefish, *Caulolatilus microps*, forced NMFS to implement temporary regulations (commercial and recreational possession limits) through an emergency action and further interim measures beginning in 2015. Prior to these measures, the price for golden tilefish would be negatively affected a few months of the year if/when fish landed in the South Atlantic derby fishery entered the New York market. The interim measures will be superseded by the Mid-Atlantic Fishery Management

Council's approved amendment to the golden tilefish FMP which will incorporate blueline tilefish as a managed species in the existing Tilefish Fishery Management Plan.

Tilefish landings are in alignment with the TAL specified for the fishery; for the 2015 FY (1 Nov. 2014–31 Oct. 2015) landings were well under the quota limit of 1.667 million lb at 1.33 million lb. For 2016 and 2017, the council has set the quota at 1.793 million pounds. According to vessel trip reports, the length of a fishing trip has been very stable over the last 3 years (ranging from 6 to 7 days) and shorter than several years before that (7–10 days), reflecting higher catch rates.

Extending the length of the fishing season is often an objective associated with the transition to catch shares and is an indicator used in program performance. Season length is often associated with economic factors allowing improved timing of harvesting with market opportunities as well as improving vessel safety as fishermen may choose when and where to fish as weather conditions allow. Recent research on the U.S. west coast showed that catch share management significantly reduced risk-taking and improved safety in the fixed gear sablefish, *Anoplopoma fimbria*, fisheries (Pfeiffer and Gratz, 2016).

The implementation of the IFQ system has particularly benefited those in the former "Part-time" and "tier 2" vessel categories of the old limited access program. These vessels can plan their fishing activities throughout the year, rather than being forced into a derby fishery on 1 Nov. (start of the fishing year) if they plan to harvest tilefish in a given year. These vessels participate in a number of other fisheries (e.g., goosefish (monkfish), *Lophius americanus*; sea scallop, *Placopecten magellanicus*; and swordfish, *Xiphias gladius*) and the IFQ system allows them to fish for tilefish when it works best for them.

Economic Performance

To determine whether a program is meeting its goals and objectives, it

is necessary to track economic performance. It is challenging to measure the economic performance of catch share programs because they are so diverse in terms of target species, location, and size. A group of NMFS employees has developed an initial set of standard performance indicators specific and relevant to catch shares (Clay et al., 2014) that measure the economic performance of national catch share programs, regardless of their design. Indicators such as catch and landings, effort, revenue, accumulation limits, and cost recovery are used as standard performance measures over time.

NOAA has become very involved, through the Catch Share Task Force, in coordinated performance monitoring of 17 current programs in the nation. The application of those indicators highlights the economic performance of all U.S. catch share programs. (Brinson and Thunberg, 2013). As they discussed, catch share programs are typically implemented coincident with enhanced catch accounting and monitoring requirements, which can reduce management uncertainty and scientific uncertainty. They found these programs were successful in having fishermen observe quota limits, reducing fishing capacity, and improving overall economic benefits and efficiency. Some distributional consequences have occurred due to reductions in the number of active vessels along with decreases in entities holding shares. In the future, some of these, and additional, performance measures will be used to review non-catch share programs as well on a periodic basis.

As the tilefish IFQ passes the 6-year anniversary of implementation of the program, the MSA requirement for periodic review of all LAPP programs in Section 303A (a) (1) (G) will ensure that a detailed and formal review take place regarding progress in meeting the goals of the program. Plans are currently underway to start the same review process for the surfclam and ocean quahog fishery. Guidance on the content and extent of these reviews is currently being re-examined.

Conclusions

Economic incentives must be aligned with society's conservation goals to create an effective policy outcome. One emerging trend is the introduction of ecosystem-based management to better address resource sustainability. Another is the growing interest in collaborative approaches to management, which provide greater opportunities for stakeholder groups to participate in the process. The use of LAPP's offers an incentive for collaborative management while also addressing economic incentives. The ability to allocate limited access privileges to fishing communities and regional groups is another use for LAPP's to help ensure economic and cultural sustainability.

While ITQ's produce gains in the aggregate, implementing them is complicated by debates over the distribution of gains among current and historical participants, and of losses from restructuring. Initial quota allocations have a significant impact on the economic well-being of fishermen. The fairness of the initial allocation to tilefish permit holders, along with transferability and accumulation of shares, were some of the most contentious issues in the tilefish FMP. Since the LAPP has been enacted, consolidation of tilefish vessels has not occurred, but vessels have gained flexibility and no vessel has an incentive to derby fish. In the surfclam and ocean quahog fishery, and in the tilefish fishery, profitability and efficiency have been enhanced.

The use of LAPP's can be effective through the continued collaboration of industry, management, scientists, and the public. Future implementation of LAPP's should be able to address many of the negative points mentioned earlier through careful planning and design, and consideration of the needs of the specific fishery.

Rapid changes have occurred under rights-based management since the idea was first identified as being a factor in the overexploitation of fishery resources, through Gordon's

(1954) seminal paper on open access exploitation.

Benefits of catch share programs can exhibit through three areas: biological stock, decrease in costs, or increase in revenue. The most notable change exhibited in these two fisheries has been on the market side, via higher ex-vessel prices due to better timing, product quality, and longer seasons.

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California's Commercial Fisheries: 1981–2012

CYNTHIA J. THOMSON

Introduction

The 1976 Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA, 1976) extended U.S. authority to 200 nmi (later named the Exclusive Economic Zone), instituted regional fishery management councils to develop and implement fishery management plans, provided national standards for those plans, and restricted foreign fishing in U.S. waters. Management priorities have shifted since the 1970's from removing foreign fleets (French et al., 1981) and encouraging domestic fishery development in the U.S. EEZ (Mansfield, 2001) to addressing overfishing and overcapitalization in domestic fisheries.

Thus the MSFCMA has been subject to two major amendments. The 1996 amendment, known as the Sustainable Fisheries Act (MSFCMA, 1996), includes provisions to prevent overfishing and rebuild overfished stocks, consider potential effects of management measures on fishing communities, minimize bycatch and bycatch mortality, and specify essential fish habitat in fishery management

plans. The 2006 amendment, known as the Magnuson–Stevens Fishery Conservation and Management Reauthorization Act (MSFCMA, 2007), includes annual catch limits and accountability measures to strengthen the provisions to end overfishing, and established conditions for implementation of catch share programs.

The Pacific Fishery Management Council (PFMC), one of the regional councils established by the MSFCMA, implemented a Pacific Salmon Fishery Management Plan (FMP) in 1977 (PFMC, 1977), a Northern Anchovy FMP in 1978 (PFMC, 1978), a Pacific Groundfish FMP in 1982 (PFMC, 1984), a Coastal Pelagic Species FMP (PFMC, 1998a) that superseded the Northern Anchovy FMP, a Highly Migratory Species FMP in 2004 (PFMC, 2003), and a Fishery Ecosystem Plan in 2013 (DeReynier, 2012; PFMC, 2013a). The MSFCMA—as well as mandates such as the Endangered Species Act (ESA)—have led to a greater focus on reducing fishery impacts not only on target species but also on other components of the ecosystem, i.e., nontarget (bycatch) species and habitat.

For instance, PFMC groundfish management includes a complex mix of harvest, effort, area, season, and gear regulations that constrain target species catches (in some cases to lev-

els well below maximum sustainable yield) to minimize bycatch of overfished stocks that comele with targeted stocks on the fishing grounds (Hilborn et al., 2011; Melnychuk et al., 2013). The PFMC has also implemented habitat protection measures, including closure of essential fish habitat to trawling (PFMC, 1998b).

PFMC management of the Pacific salmon, *Oncorhynchus* spp., fishery is similarly driven by the need to restrict the level, location, and timing of harvest of more abundant stocks to minimize bycatch of “weak” stocks (including ESA-listed salmonids) that co-mingle with these more abundant stocks in the ocean fishery (Satterthwaite, 2014). Other examples of bycatch concerns addressed by the PFMC include restrictions on salmon bycatch by Pacific whiting, *Merluccius productus*, trawlers (PFMC, 1997), groundfish bycatch by shrimp, *Pandalus jordani*, trawlers (Hannah and Jones, 2007), and sea turtle, *Dermochelys coriacea*, *Caretta caretta*, *Chelonia mydas*, and *Lepidochelys olivacea*, bycatch by swordfish, *Xiphias gladius*, pelagic longline and drift gillnet vessels (Caretta et al., 2004; PFMC, 2013b). In 2008 the PFMC added krill, *Euphausiacea*, to the Coastal Pelagic Species FMP and placed a ban on harvest of these important forage species (PFMC, 2008b).

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ABSTRACT—This paper discusses the diverse and dynamic nature of California's commercial fisheries and the resource, environmental, economic, and regulatory factors that affected participation, landings, and ex-vessel revenues during 1981–2012. Fishery trends are a simplistic and some-

times misleading basis for judging management performance, as increasing and decreasing trends can occur for a variety of reasons. An important management responsibility is to ensure that harvest restrictions are responsive to stock dynamics, regardless of their cause. I highlight a number

of socioeconomic characteristics (e.g., the positive effect of fishery diversification and geographic mobility on vessel revenues, the high proportion of vessels that land exclusively in one port, the patterns of movement among fisheries) that should be considered in management decision making.

Fishery management has changed at the state level as well. In 1998 the State of California enacted the Marine Life Management Act (MLMA, 1998), which expanded the focus of state management to include not just exploited marine populations but marine wildlife and marine habitat in general. The MLMA includes some provisions that are similar to the federal MSFCMA—e.g., rebuilding depressed stocks, reducing bycatch, and considering effects on fishing communities.

One important outcome of the MLMA was development of the State Nearshore Finfish Management Plan (NFMP) in 2002 (CDFG, 2002). The 19 species included in the NFMP overlap with some of the species in the PFMC's Groundfish FMP; the two plans complement and enhance protection of these overlapping species. In 1999 the state enacted the Marine Life Protection Act (MLPA, 1999), which mandated the establishment of a system of marine protected areas (MPA's). During 2007–12, MPA's were implemented in four designated regions encompassing the California coast; MPA's for the fifth region (San Francisco Bay) will be considered at a future date (Saarman and Carr, 2013).

This paper provides a retrospective view of California commercial fisheries over the past three decades.¹ Changes in management strategies, such as those cited above, have influenced fishery trends. However, some caution is warranted in interpreting these trends, as the effectiveness of current management cannot be determined solely on the basis of whether a trend is up or down. Declining harvests may be indicative of poor or nonexistent management, but they can also occur when management is proactive and responsive to changes in stock abundance. Managers cannot be expected to sustain the harvest levels achieved in a developing fishery, as

the dynamics of exploited fish stocks make harvest reductions inevitable, even in well-managed fisheries.

Management should be considered in the context of other factors that also affect fishery trends. Environmental conditions (e.g., El Niño/Southern Oscillation, Pacific Decadal Oscillation, climate change) can have short- to long-term effects on the abundance and distribution of target and bycatch species (MacCall, 1996; Mantua et al., 1997; Lindegren and Checkley, 2013). Economic factors (e.g., domestic and global seafood demand, conditions in other U.S. and foreign fisheries that supply the same markets as California fisheries, ex-vessel prices, fishing costs) can influence the development and decline of fisheries and the amount of pressure exerted on particular stocks (Vojkovich, 1998; Herrick et al., 2006; Knapp et al., 2007; Anderson et al., 2011).

Technological change can also affect harvest opportunities. For instance, fish finding and harvesting technology can improve harvest efficiency (although competitive advantage may be diminished to the extent that adoption of such methods becomes widespread); changes of this type have led to standardization of effort in stock assessments to avoid confounding the effects of fishing power and stock abundance on CPUE (Maunder and Punt, 2004). Technology also includes methods to reduce take of nontarget species (e.g., bycatch reduction devices) and discourage fishing in certain habitats (e.g., use of small footropes to discourage trawling in rocky habitat). Life history characteristics of target and bycatch species and other biological traits, such as habitat preferences and schooling behavior, can affect their vulnerability to fishing and their ability to recover from overfishing and environmental adversity.

Stock assessments reflect the biology of the species and the influence of historical catches and environmental conditions on current abundance (Methot et al., 2013). Harvest control rules adopted by the PFMC ensure that the outcome of stock assessments

are reflected in annual catch limits (ACL's). Catches, in turn, affect future stock trajectories.

Stocks are typically assessed throughout their geographic range. Harvest control rules likewise are used to establish ACL's for entire stocks which can be suballocated among fishery sectors and geographic areas. Catches by any particular sector (e.g., California commercial) may or may not be correlated with stock abundance, depending on factors such as the distribution of the fishery relative to the distribution of the stock. Weak-stock management policies constrain target species harvests (often below levels warranted solely by target species abundance) to achieve desired reductions in bycatch of weak stocks. Inferences regarding abundance from harvest trends should be made with such factors in mind.

This paper describes California fishery trends in terms of three indicators: vessel participation, landings, and ex-vessel revenue. As will be seen, these indicators do not necessarily follow similar patterns for a given fishery, and they can also differ depending on the temporal and geographic scale at which they are depicted. Different indicators and scales provide different insights into fisheries and underscore the need for nuanced interpretation of the data. California fisheries are diverse, not just in terms of species, gear type, fishing strategies, location, and trends, but also in terms of the factors that influence those trends.

The section on California landings during 1916–2012 focuses on trends in several historically significant fisheries. Later sections provide a more detailed description of fishery trends in the recent decades, 1981–2012, as summarized from vessel-level landings receipts data that have been available in electronic form since 1981. Specifically, information is provided on statewide trends in individual fisheries in terms of participation, landings, and ex-vessel revenues. Also, more geographic specificity is given by describing overall fishery trends by region and port and highlighting fisheries that are particularly influential in

¹See McEvoy (1986) and Mason (2004) for insightful perspectives on long-term trends in California fisheries. See Leet et al. (2001) for detailed, species-specific descriptions of California landings trends, population status, and fishery management prior to 2000.

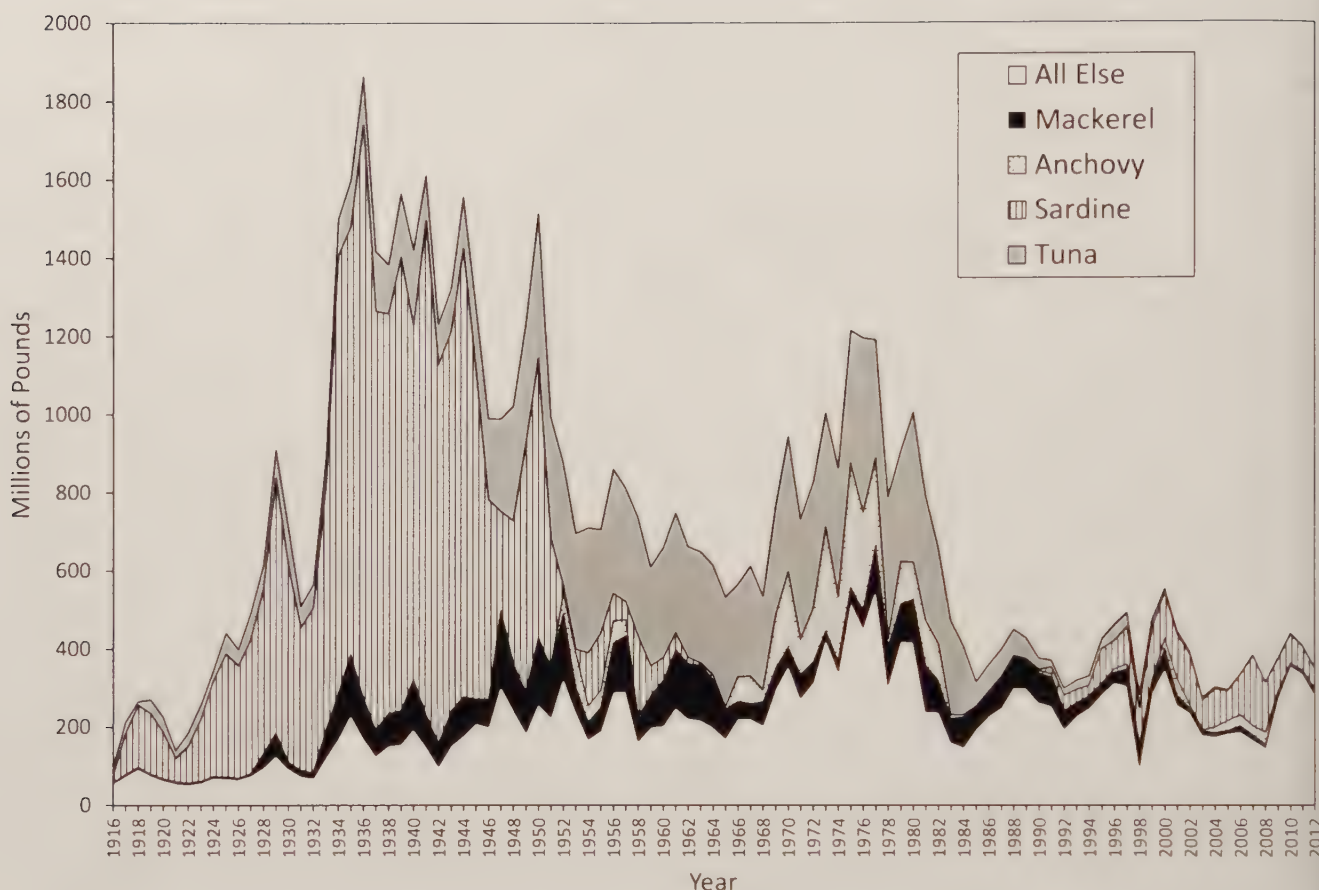


Figure 1.—California commercial landings, 1916–2012 (sources: Leet et al., 2001 and PacFIN).

each geographic area. Finally, vessel behavior is described as it relates to revenues, fishery diversification, and geographic mobility. Then conclusions are drawn from analyses contained in the previous sections.

All landings volumes are reported here in landed weight and all dollar values are corrected for inflation to base year 2012. Trips are assigned to fisheries based on the species/gear combination accounting for the plurality of revenue earned on the trip. A vessel that made at least one trip in a given fishery is designated a participant in that fishery.

California Commercial Fishery Trends 1916–2012

Figure 1 provides a historical perspective on California commercial landings since 1916. Notable landings peaks occurred during 1934–48

(1.2–1.8 billion lb), 1949–50 (1.1–1.3 billion lb), and 1975–77 (856–901 million lb). The major contributor to the first two peaks was the Pacific sardine, *Sardinops sagax*, fishery, while tuna, *Thunnus* spp., and northern anchovy, *Engraulis mordax*, were major contributors to the third peak.

Landings of coastal pelagic species—Pacific sardine; northern anchovy; Pacific mackerel, *Scomber japonicas*; and jack mackerel, *Trachurus symmetricus*—have varied widely in both absolute and relative terms since 1916. Demand for canned sardines developed during World War I and was soon overshadowed by the more lucrative market for fish meal and oil, which were produced from cannery waste by a process known as reduction. California processors operated reduction plants in conjunction with canneries, then further augmented meal and oil

production by using whole fish for reduction. During 1920–41, concerns expressed by CDFG and federal biologists led to passage of various state laws intended to reserve use of sardines for human consumption. Processors circumvented these laws by harvesting and reducing sardines outside the state's 3-mile jurisdiction, a situation that continued until 1938, when fish meal and oil prices fell and an amendment to the California Constitution gave the state the authority to stop offshore reduction (Ueber and MacCall, 1992). During the 1930's and 1940's, the sardine stock (which expands its range as abundance increases) supported high-volume fisheries from Mexico to British Columbia (Radovich, 1982). Sardines comprised 44–62% of total California landings during 1917–23 and 70–83% in 1924–45. California sardine landings rou-

tinely exceeded 900 million lb during 1934–44, peaking at 1.5 billion lb in 1936.

The collapse of the California fishery in the 1950's (preceded by collapse of the British Columbia, Washington, and Oregon fisheries in the 1940's) has been attributed to a combination of overfishing and adverse environmental conditions (Marr, 1960; McEvoy, 1986; Ueber and MacCall, 1992). The State of California imposed a moratorium on directed sardine landings in 1974 which was lifted in 1986 (Wolf, 1992) under a harvest regime that continued in similar form when a federal Coastal Pelagics Species (CPS) Fishery Management Plan that included sardine was implemented in 2000 (PFMC, 1998a).

The collapse of the sardine fishery in the 1950's was followed by development of the northern anchovy reduction fishery in 1966, which peaked at 317 million lb in 1975 and ceased operation by the late 1980's, when record low reduction prices made the fishery unviable (CDFG, 1990:13–14). CPS landings were subsequently dominated by mackerel until the mid-1990's, when the sardine stock had recovered sufficiently to support a substantial fishery. Since then, sardine landings reached a high of 179 million lb in 2007—a substantial volume but well below the amounts harvested in the heyday of the fishery. Sardines are now marketed for non-reduction uses, including human consumption, aquaculture feed, and bait in recreational and commercial fisheries (Herrick et al., 2006).

The tuna fishery expanded as demand for canned tuna increased after World War II. Tuna landings increased from 10–99 million lb during 1916–33 to 94–194 million lb during 1934–45, and peaked at 176–384 million lb during 1946–83 (except for the record 1976 year, when harvest reached 447 million lb). Landings subsequently declined to 176 million lb in 1984 to an average of 64 million lb during 1985–89, 28 million lb during 1990–99, and 4 million lb during 2000–12. Tunas comprised 23–62% of total California

landings during the peak years 1946–83, but less than 2% during 2000–12. Tuna harvests included troll landings of premium “white meat” albacore tuna, *Thunnus alalunga*, and higher-volume landings of yellowfin, *T. albacares*, and skipjack, *Katsuwonus pelamis*, by tuna clipper “baitboats” and later seiners. Albacore constituted the plurality if not majority of California tuna landings during 1916–25 and 1999–2012, while yellowfin constituted the plurality/majority for 67 of the 73 years 1926–98 (skipjack being the plurality/majority in the remaining 6 years).

Until the late 1950's, yellowfin and skipjack tunas were targeted by baitboat fishermen who used chum to attract tunas and employed poles with short lines and barbless hooks to heave the fish over their shoulders onto the deck (Godsil, 1938). Improved refrigeration methods in the 1930's enabled these boats to extend their range farther south and offshore. By the late 1950's, technological improvements (nylon nets, Puretic powerblock²) led to development of the tuna purse seine fishery.

California seiners were of two distinctive types. One fleet consisted of smaller “wetfish” boats (25–150 short tons capacity), based in the San Pedro area, that targeted CPS finfishes, market squid, *Loligo opalescens*, and also tunas in years when they appeared in coastal waters of the Southern California Bight (Perrin and Noetzel, 1970). In addition to newer boats, the wetfish fleet also included seiners that had participated in the sardine fishery before its collapse (Knaggs, 1973). The second fleet consisted of large “super-seiners” (200–2,000 short ton capacity) that made long-range trips to the eastern Pacific Ocean to harvest tropical tunas, such as yellowfin and skipjack (Orbach, 1977; Rockland, 1978). This fleet included baitboats that had been converted to purse seiners as well as newly built seiners. The rapid expansion of this long-range fleet was

²Mention of trade names and commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA

facilitated by federal programs that encouraged capitalization and investment in fisheries.³

The Inter-American Tropical Tuna Commission manages yellowfin tuna within the Commission's Yellowfin Regulatory Area (CYRA). Concerns regarding incidental mortality of pan-tropical spotted, *Stenella attenuata*; spinner, *S. longirostris*; and common, *Delphinus delphis*, dolphins by seiners in the CYRA in the late 1960's prompted technological changes that reduced dolphin mortality by U.S. seiners to minimal levels by the early 1980's (Coe et al., 1984). Landings by the high-seas fleet in California also plummeted by the early 1980's as tax advantages and lower costs caused tuna canneries to close their operations in southern California in favor of Puerto Rico and American Samoa (Francis et al., 1992).⁴ The last tuna

³Federal support for capitalization and modernization of fishing fleets has taken the form of programs such as the Fisheries Loan Fund (FLF, 1957–73), the Fishing Vessel Mortgage Insurance Program (1962–72), the Fishing Vessel Obligation Guarantee Program (FVOG, 1973–98), the Fisheries Finance Program (1998 to present, including new authority to finance buyback programs and purchase of catch shares by small-scale fishermen and crew members), and the Capital Construction Fund (1970–present). The terms of these programs are specified in legislation such as the 1956 Fish and Wildlife Act, the 1972 Federal Ship Financing Act, and the 1996 Sustainable Fisheries Act as amendments to the 1936 Merchant Marine Act, and reflect the federal government's broader agenda regarding development of the shipping industry. These programs were implemented by the Department of the Interior's Bureau of Commercial Fisheries (BCF) until 1970, when the functions of the BCF were transferred to the newly-established National Marine Fisheries Service (NMFS). During the late 1950's and early 1960's the BCF issued FLF loans for conversion of 30 baitboats to purse seiners (an additional 70 boats were converted using private funds). Although the FVOG program has experienced very low default rates, a notable exception occurred in 1996, when NMFS seized and auctioned 6 super-seiners (all owned by the same family) for \$26.2 million after low yellowfin prices prompted the family to default on \$21 million in loans they had received in the late 1980's and early 1990's. In 1996, NMFS administratively banned the use of FVOG funds for new vessel construction or for refurbishment of existing vessels that materially increased the vessel's harvesting capacity (FFITE, 1999)

⁴During the 1970's, the U.S. distant-water tuna fleet operated principally in the Eastern Tropical Pacific and landed their catch at canneries in California and Puerto Rico; many of these vessels were owned by U.S. processors. In the late

cannery in southern California closed in 2001 (PFMC, 2016b). Since then, the relatively modest amounts of tuna still landed in California have been exported overseas for processing.

California Fishery Trends 1981–2012

This section provides a post-1980 overview of California's commercial fisheries. The information provided here illustrates the diverse and dynamic nature of fishing activity, the varying insights that can be gained by considering fisheries at differing spatial and temporal scales, and the resource, environmental, regulatory, and socioeconomic factors affecting fishery trends. Because vessel behavior, fishery regulations, and ecosystem effects are typically differentiated by gear as well as species, fisheries are depicted here in terms of species/gear combinations.

Table 1 summarizes landings, revenues, and vessel participation trends in the 27 California fisheries that generated at least \$400,000 in average annual ex-vessel revenue during 1981–2012. Participation tends to be highest in line and pot fisheries, and landings volume highest in net (seine and trawl) fisheries. Ex-vessel revenue does not necessarily correlate with landings, as

Table 1.—Average annual number of boats, landings (millions of pounds landed weight), and revenue (\$millions, base year=2012) for top-27 California fisheries (based on 1981–2012 average revenue), 1981–2012, by fishery and time interval. Number of boats not additive across fisheries, as some boats participate in multiple fisheries.

	1981–2012 Avg	1981–85 Avg	1986–90 Avg	1991–95 Avg	1996–2000 Avg	2001–05 Avg	2006–10 Avg	2011–12 Avg
Tuna seine								
Boats	54	146	71	50	52	19	5	9
Landings	42.4	184.5	49.0	15.7	19.6	2.0	0.4	0.2
Revenue	39.9	189.7	43.7	9.3	11.5	1.0	0.2	0.3
Dungeness crab pot								
Boats	541	630	639	655	501	425	424	463
Landings	11.9	6.8	8.3	9.4	9.6	13.9	16.6	23.2
Revenue	26.7	17.0	20.2	18.7	23.4	28.4	35.8	69.1
Squid seine								
Boats	93	88	84	77	115	98	91	113
Landings	114.5	23.0	65.1	96.2	160.7	132.3	159.0	241.6
Revenue	24.6	5.6	9.6	16.0	28.1	27.1	44.7	65.9
Non-whiting groundfish trawl								
Boats	137	210	194	178	149	88	47	31
Landings	38.5	75.6	60.1	44.4	33.9	15.5	13.2	9.9
Revenue	21.8	34.7	33.5	26.7	22.0	10.4	9.1	7.2
Sea urchin dive								
Boats	266	223	393	448	283	184	116	133
Landings	21.6	19.5	45.4	29.6	15.6	12.4	11.1	11.5
Revenue	18.6	8.3	29.8	40.9	19.0	10.7	6.9	8.2
Salmon troll								
Boats	1,378	3,220	2,429	1,241	774	680	258	541
Landings	4.2	4.8	8.4	3.5	4.0	4.9	0.6	1.7
Revenue	16.0	24.4	37.5	11.0	9.1	13.4	3.1	9.1
CPS seine								
Boats	95	155	134	92	88	65	53	56
Landings	130.8	167.4	129.2	85.9	153.4	130.0	144.3	67.4
Revenue	12.6	26.3	16.7	7.9	10.3	7.5	9.4	5.5
Groundfish fixed gear								
Boats	889	1,156	1,147	1,172	978	564	474	493
Landings	6.9	10.4	9.0	9.5	6.4	3.2	3.8	4.9
Revenue	10.2	8.6	9.2	11.8	12.0	7.8	9.9	14.6
Albacore troll								
Boats	354	996	229	173	414	276	113	164
Landings	8.0	22.9	6.6	6.4	9.8	4.0	1.1	1.4
Revenue	9.2	27.9	6.5	6.9	10.8	3.9	1.5	2.6
Herring net								
Boats	192	392	350	205	156	88	28	27
Landings	9.8	16.0	18.3	11.4	10.1	4.4	1.2	3.4
Revenue	7.4	14.4	10.5	10.1	9.8	2.0	0.4	0.6
Swordfish net								
Boats	102	184	171	120	93	44	33	18
Landings	1.4	2.7	2.3	1.6	1.1	0.4	0.5	0.2
Revenue	7.0	13.8	14.6	8.5	4.5	1.6	1.7	0.8
Lobster pot								
Boats	204	235	223	247	202	164	163	180
Landings	0.6	0.5	0.6	0.6	0.7	0.8	0.7	0.8
Revenue	6.6	3.7	5.3	5.7	6.7	6.5	9.1	13.5
Pink shrimp trawl								
Boats	52	56	72	94	80	18	7	12
Landings	5.8	3.0	9.6	10.9	6.4	2.8	1.9	6.8
Revenue	4.0	3.0	7.9	7.5	4.1	1.2	0.7	3.3

Table continued

1970's, some Latin American countries established 200-mile exclusive economic zones and expanded their own fleets, prompting U.S. processors to increase their purchases of cheaper, raw tuna from foreign sources. The U.S. fleet declined from 101 to 66 active vessels from 1979 to 1988, with many of these boats transferring to foreign registry. As indicated by Sakagawa (1991), these transfers were due to prevailing economic conditions (low ex-vessel yellowfin prices, debt service, interest by foreign entities in purchasing U.S. vessels) rather than U.S. tuna–dolphin regulations. Although the dolphin quota became more constraining during this period (declining from 78,000 animals in 1976 to 20,500 animals in 1981 and thereafter), the U.S. fleet stayed within the quota in all but two years (1976 and 1982). U.S. processors closed most of their canneries in southern California and Hawaii during 1979–85 and expanded their operations in American Samoa and Puerto Rico. Canners in insular territories enjoy economic advantages such as exemption from the Nicholson Act (which prohibits foreign vessels from landing fish taken in high-seas fisheries), duty-free entry of cannery products into the U.S., and exemption from federal minimum wage standards (Levine and Allen, 2009).

revenue depends on ex-vessel price as well as volume landed.

Fishery Participation

The number of boats participating in California fisheries declined from 6,892 in 1981 to 1,479 in 2009, then increased to 1,877 by 2012. Participation trends are driven largely by three fisheries: Pacific salmon troll, groundfish fixed gear, and Dungeness crab, *Cancer magister* (Fig. 2). Due to the sheer number of salmon trollers, the salmon fishery has tended to drive the overall statewide pattern of vessel participation. Participation in

the groundfish fixed gear and Dungeness crab fisheries has also been substantial but more stable than salmon participation.

Salmon Troll

The salmon troll fishery, one of the oldest fisheries in California, expanded during World War II (Fig. 3), encouraged by favorable market conditions, modest capital requirements for vessel entry, and lack of regulatory controls on entry. By the 1980's, however, participation was on a downward trend, declining from 4,155 boats in 1981 to 2,094 boats in 1990, then

Table 1.—Continued

	1981–2012 Avg	1981–85 Avg	1986–90 Avg	1991–95 Avg	1996–2000 Avg	2001–05 Avg	2006–10 Avg	2011–12 Avg
Swordfish line/harpoon								
Boats	67	135	88	61	57	47	30	22
Landings	0.8	0.3	0.3	0.5	1.5	1.9	0.2	0.6
Revenue	3.1	2.0	2.3	2.9	5.5	5.8	1.0	2.0
Halibut net/trawl								
Boats	159	267	251	154	144	108	70	61
Landings	0.8	1.2	1.0	0.7	1.0	0.7	0.4	0.3
Revenue	2.9	3.8	3.9	2.6	3.3	2.7	1.8	1.4
Abalone dive								
Boats	61	139	115	104	29	0	0	0
Landings	0.3	1.0	0.6	0.4	0.1	0.0	0.0	0.0
Revenue	2.3	5.0	4.6	4.3	1.0	0.0	0.0	0.0
Rock crab pot								
Boats	139	142	158	163	156	140	92	101
Landings	1.4	1.4	1.7	1.4	1.2	1.4	1.3	1.7
Revenue	2.2	2.3	2.7	2.1	1.9	2.1	1.8	2.3
Groundfish net								
Boats	100	240	238	103	33	15	8	5
Landings	2.8	6.2	8.5	2.8	0.4	0.0	0.0	0.0
Revenue	2.0	4.3	6.0	1.9	0.3	0.0	0.0	0.0
Prawn pot								
Boats	38	8	36	58	56	39	32	32
Landings	0.2	0.0	0.1	0.2	0.2	0.3	0.3	0.5
Revenue	2.0	0.1	0.9	1.6	2.2	2.8	3.6	4.6
Prawn trawl								
Boats	34	39	32	38	58	36	12	14
Landings	0.5	0.5	0.3	0.3	1.3	0.4	0.3	0.2
Revenue	1.9	1.5	0.8	1.8	5.5	1.5	0.7	0.5
Shark net								
Boats	142	291	254	138	101	66	46	34
Landings	1.1	3.0	1.7	0.8	0.6	0.5	0.3	0.1
Revenue	1.7	4.7	2.9	1.3	1.1	0.7	0.4	0.2
White seabass net								
Boats	89	85	80	68	69	91	90	224
Landings	0.3	0.2	0.1	0.1	0.2	0.3	0.5	0.5
Revenue	0.7	0.8	0.4	0.3	0.4	0.8	1.3	1.5
Whiting trawl								
Boats	7	11	9	6	8	4	7	0
Landings	7.7	3.5	11.8	10.0	9.3	6.8	7.7	0.0
Revenue	0.6	0.5	1.3	0.8	0.6	0.4	0.6	0.0
Sea cucumber trawl/dive								
Boats	40	8	11	68	57	49	41	57
Landings	0.5	0.0	0.1	0.6	0.6	0.7	0.5	0.6
Revenue	0.6	0.0	0.0	0.5	0.6	0.7	1.0	2.6
Halibut line								
Boats	205	104	182	239	253	232	205	244
Landings	0.1	0.0	0.1	0.1	0.2	0.2	0.1	0.1
Revenue	0.5	0.1	0.4	0.5	0.6	0.7	0.7	0.7
Shrimp pot								
Boats	11	2	13	15	14	17	8	9
Landings	0.7	0.0	0.5	1.3	1.4	0.8	0.3	0.3
Revenue	0.5	0.0	0.5	0.9	1.0	0.4	0.2	0.3
Hagfish pot								
Boats	14	0	27	2	1	1	44	27
Landings	0.6	0.0	1.6	0.1	0.0	0.0	1.3	1.1
Revenue	0.4	0.0	1.1	0.0	0.0	0.0	1.0	0.8

formed California's troll fishery from a two-species fishery to a Chinook, *O. tshawytscha*-only fishery (PFMC, 2016a).

Groundfish Fixed Gear

Groundfish fixed gear (hook-and-line and pot) vessels target sablefish, *Anoplopoma fimbria*, as well as rockfish (*Sebastes* spp.), lingcod, *Ophiodon elongatus*, and other groundfish species. Average annual prices increased steadily from \$0.82/lb during 1981–85 to \$2.98/lb by 2011–12. Despite these price increases, participation declined from 1,367 boats in 1981 to 446–513 boats since 2004 (Fig. 2). The PFMC implemented a groundfish limited entry program in 1994 that included fixed gear as well as trawl vessels (PFMC, 1992). Other regulations affecting participation include the fixed gear sablefish endorsement (1997) and permit stacking (2001–02) (PFMC, 2014a), as well as more restrictive ACL's to facilitate rebuilding of overfished rockfishes. The State of California responded to the development of a lucrative live-fishery fishery for nearshore rockfishes in the late 1980's by imposing increasingly restrictive harvest limits, MPA's, and a statewide moratorium on entry in 2000 (CDFG, 2002), followed by a restricted access program in 2003 (CDFG⁵). Regulatory constraints affected landings as well as participation. Fixed gear landings increased fairly steadily from 7.0 million lb in 1984 to 12.9 million lb in 1992 but have been on a downward trajectory ever since (4.0 million lb in 2012).

Dungeness Crab Pot

Participation in the Dungeness crab fishery declined from 645–814 boats during 1981–94 to 533–612 boats during 1995–99 to 401–479 boats during 2000–10, then increased to 466–487 boats during 2011–12 (Fig. 2). The State of California manages the fishery based on “3-S” principles—sex, size, and season. Harvest is limited to male

⁵CDFG. 2007. Groundfish open access permitting. Ver. 27 July 2007, 4 p. Available online at <https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=33992>.

falling more abruptly to 610 by 2007 (Fig. 2). Participation was negligible during 2008–10 due to record low escapements and landings, including unprecedented fishery closures in 2008 and 2009 (PFMC, 2008a; Lindley et al., 2009), then increased to 621 boats by 2012 as stocks experienced a modest rebound. The dependence of salmonids on freshwater as well as ocean habitat contributes to the vulnerability of these species in drought-prone California. Salmon trollers comprised 41–61% of California vessels during

1981–91 and 25–37% during 1992–2007 and 2011–12.

Factors contributing to the decline in participation include establishment of a limited entry program in 1983 (Deweese and Weber, 2001), declining ex-vessel prices, and increasingly restrictive management since the early 1990's (including weak-stock management policies). A particularly notable example of the latter is the prohibition on coho, *O. kisutch*, retention since 1993 to protect endangered Central California Coast coho; this trans-

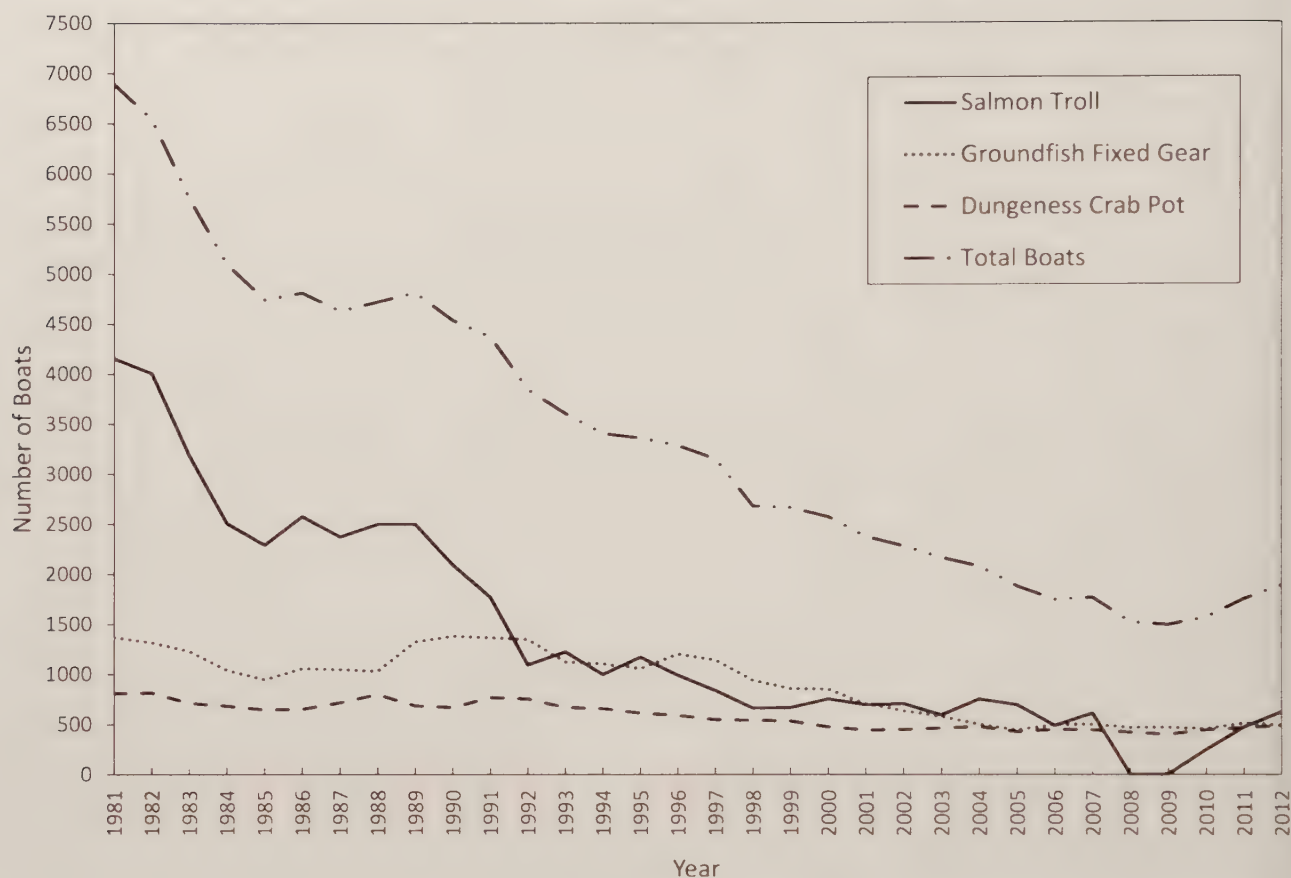


Figure 2.—Total number of boats participating in California commercial fisheries, and number participating in selected fisheries (salmon troll, groundfish fixed gear, Dungeness crab pot), 1981–2012. Boats are not additive across fisheries as some boats participate in multiple fisheries.

crabs that exceed a given size limit, and seasons are imposed to discourage harvest of soft-shelled crabs (Hankin and Warner, 2001). The state established a limited entry program in 1995, and trap limits were implemented beginning in 2013 (CDFG, 2012). Fishery participation is affected by species availability, prices, and (particularly since this is a winter fishery) weather.

Landings

California landings fell precipitously from 792 million lb in 1981 to 359 million lb in 1985, largely due to the decline in tuna seine landings from 290 to 47 million lb and the decline in anchovy landings from 115 to 4 million lb. Since 1985, total landings have been variable with no apparent trend. Highs were experienced in 1988 (496

million lb), 1997 (492 million lb), and 2000 (554 million lb); lows were experienced in 1998 (284 million lb) and 2003 (275 million lb) (Fig. 4). Overall landings have trended toward an increase in invertebrate species relative to finfishes. Fisheries that have had the most notable effects on landings are the high-volume seine fisheries for tunas, market squid, and coastal pelagic species (CPS).

Tuna Seine

Tuna seine landings declined from 290 million lb in 1981 to 47 million lb in 1985, then stabilized at 46–62 million lb during 1986–89. Landings continued their downward slide to 12–29 million lb in 1990–99 and 2–5 million lb in 2000–05, and have averaged 352,000 lb since 2005. The precipitous

decline in tuna landings that occurred in the early 1980's is largely due to the overseas relocation of southern California tuna canneries that began in the late 1970's. The last remaining southern California cannery closed in 2001 and most tuna landings are now processed out-of-state (PFMC, 2016b).

Squid Seine

Unlike the tuna and CPS fisheries—which have a long history of substantial landings in California (Fig. 1)—the fishery for market squid did not experience appreciable growth until the 1980's, when overseas markets in Asia and Europe expanded and U.S. consumers acquired a taste for squid (better known as “calamari”). With the notable exception of 1998 (a low-landings year with record high prices

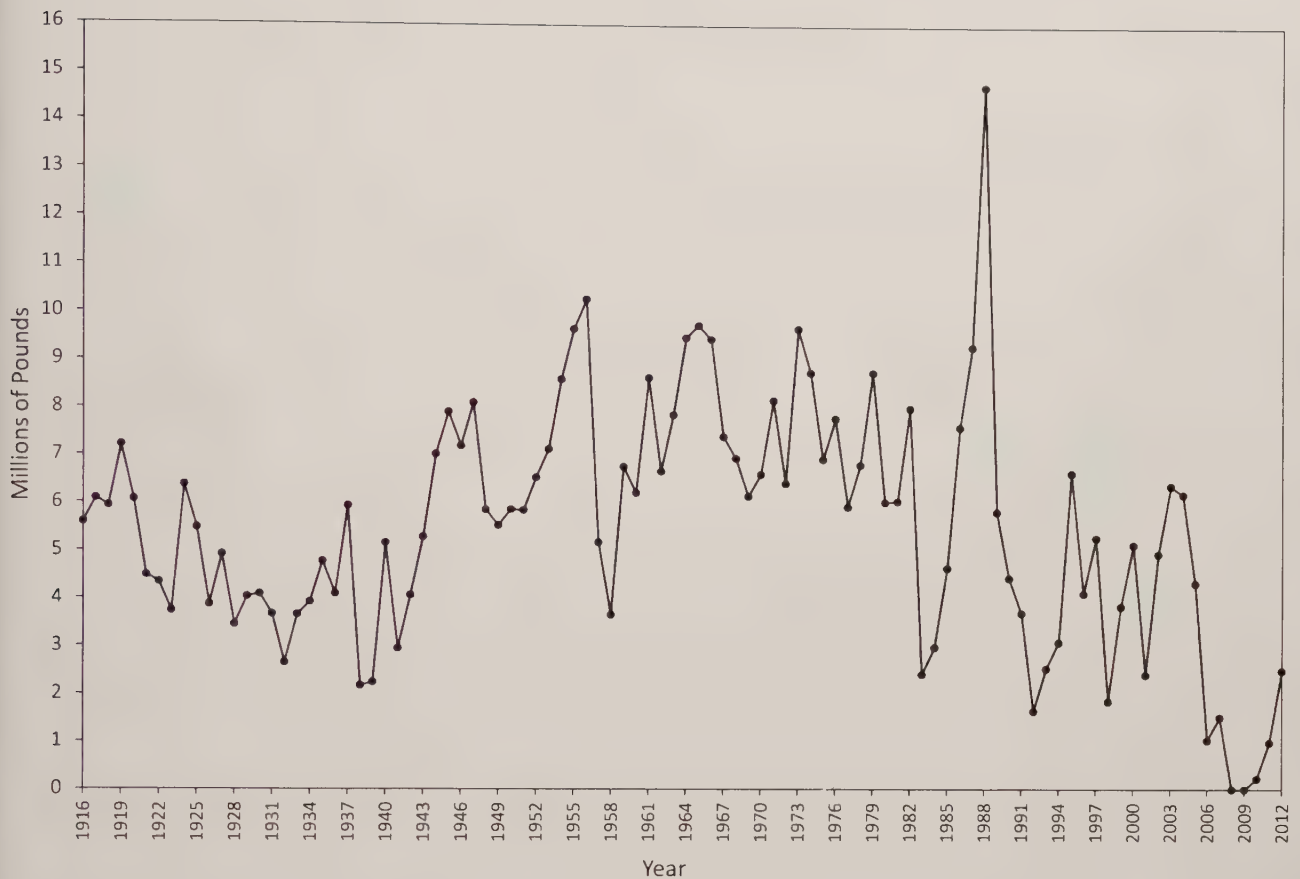


Figure 3.—California ocean commercial salmon landings, 1916–2012 (sources: Leet et al., 2001 and PacFIN).

averaging \$0.34/lb), squid prices generally increased from \$0.11–0.22/lb during 1986–2002 to \$0.25–0.33/lb in 2003–12. Since 1985, squid has vied with CPS as the largest volume fishery in California. Since 2009, squid landings (205–288 million lb) have consistently exceeded CPS landings (65–105 million lb).

Squid availability is highly susceptible to environmental conditions (Koslow and Allen, 2011); record-low landings in 1983, 1984, 1992, and 1998 (1.2–28.9 million lb) coincided with major El Niño events that adversely affected the availability of squid to the fishery. State regulations include quotas, restricted access, weekend closures, and restrictions on the use of squid attracting lights to mitigate effects on seabird colonies (CDFG, 2005). The 2012–13 season was the third consecutive season to be

curtailed due to the quota constraint (CDFW, 2013).

CPS Seine

CPS seine landings averaged 131 million lb during 1981–2012. Landings exceeded 200 million lb in 1981–82 and 2007, and fell below 100 million lb in 1992–94 and 2010–12. During 1981–82, CPS landings were about evenly split between anchovy and Pacific and jack mackerel. The anchovy reduction fishery ceased operation in the late 1980's due to record low reduction prices (Jacobson and Thomson, 1993). The mackerel share of CPS landings grew to 86–95% during 1983–90, then declined to 50% by 1992 as the sardine fishery recovered after its collapse in the 1950's.

During 1995–2012, the species composition of CPS landings was 76% sardine, 14% mackerel, and 10% an-

chovy on an average annual basis. As sardine abundance has increased, the stock has expanded its northward range from Mexico and California to include Oregon, Washington, and British Columbia (Hill et al., 2014). The sardine harvest control rule is notable for incorporating ocean temperature as a constraint on harvest to reflect the effect of environmental conditions on recruitment.⁶

Other Fisheries

Although much lower than squid and CPS landings, landings in the sea urchin, *Strongylocentrotus* spp., non-whiting groundfish trawl, and Dunge-

⁶The temperature component of the sardine harvest control rule was abandoned in 2012 but re-instated in 2014 on the basis of further research indicating the appropriateness of its inclusion using a different temperature index (Lindgren and Checkley, 2013; Jacobson and McClatchie, 2013).

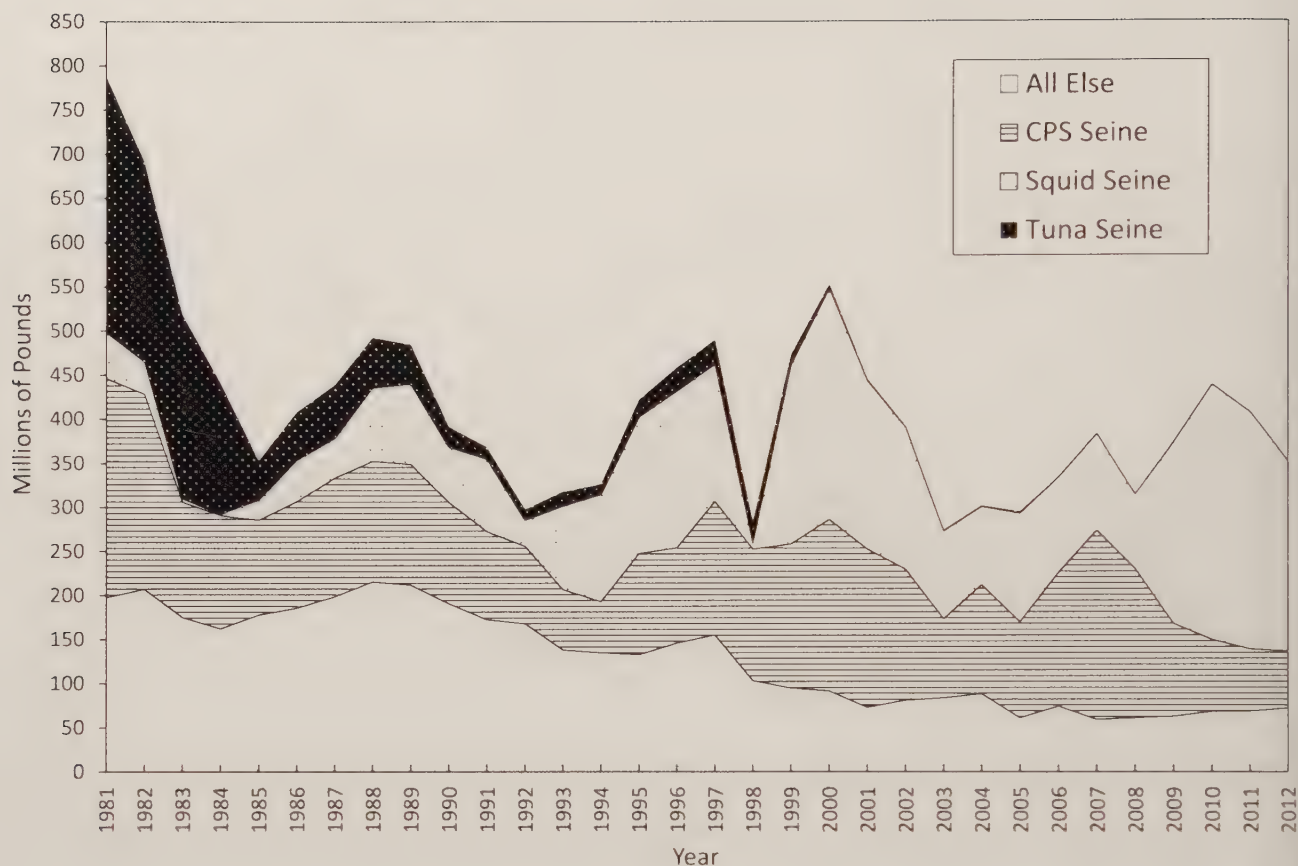


Figure 4.—California commercial landings, including landings in selected fisheries (tuna seine, squid seine, CPS seine), 1981–2012.

ness crab fisheries have nonetheless been substantial, typically ranging in the tens of millions of pounds.

- The fishery for sea urchin roe (uni) originally developed for the Japanese market and later expanded to include the domestic market as U.S. consumers acquired a taste for sushi (Kalvass and Rogers-Bennett, 2001). Urchin landings increased from 15–26 million lb during 1981–85 to 33–52 million lb during 1986–92. Landings declined to 27 million lb in 1993 and 18 million lb by 1997 and have been relatively stable (10–15 million lb) since 1998.
- Landings in the groundfish trawl fishery steadily declined from 77 million lb in 1981 to 10 million lb in 2012. In the late 1990’s–early 2000’s, the PFMC declared eight

groundfish stocks “overfished” (Ralston, 2002b) and implemented major reductions in harvest limits for both overfished stocks and target species that co-mingle with these stocks in the fishery, area and gear restrictions to minimize incidental take of overfished stocks, and other rebuilding measures.⁷ An industry-funded buy-back was implemented in 2003 to address the overcapacity problem, which had been exacerbated by the

⁷These unprecedented restrictions were intended to put the fishery on a more sustainable trajectory after major flaws were uncovered in the scientific information previously used to set harvest limits. According to Ralston (2002a), “...for years there were serious flaws in the scientific advice that was presented to the council as the foundation of its decision making. The deficiencies were not easy to foresee and were due to a combination of inadequate data and fishery productivity that was far lower than anyone imagined.”

reduction in harvest opportunities (NMFS, 2004). A catch share program was implemented in 2011 that increased individual accountability for incidental take of overfished stocks while also providing additional harvest opportunity for targeted species (PFMC, 2010a; PFMC, 2010b). Groundfish trawl activity is monitored via landings receipts, logbooks, satellite-based vessel monitoring systems, and 100% observer coverage; groundfish processors as well as vessels are subject to mandatory economic data collection requirements.

- Landings in the Dungeness crab fishery increased from 4–14 million lb during 1981–2002 to 9–26 million lb in 2003–12. Landings exceeded 20 million lb in 6 of the 10 years since 2003.

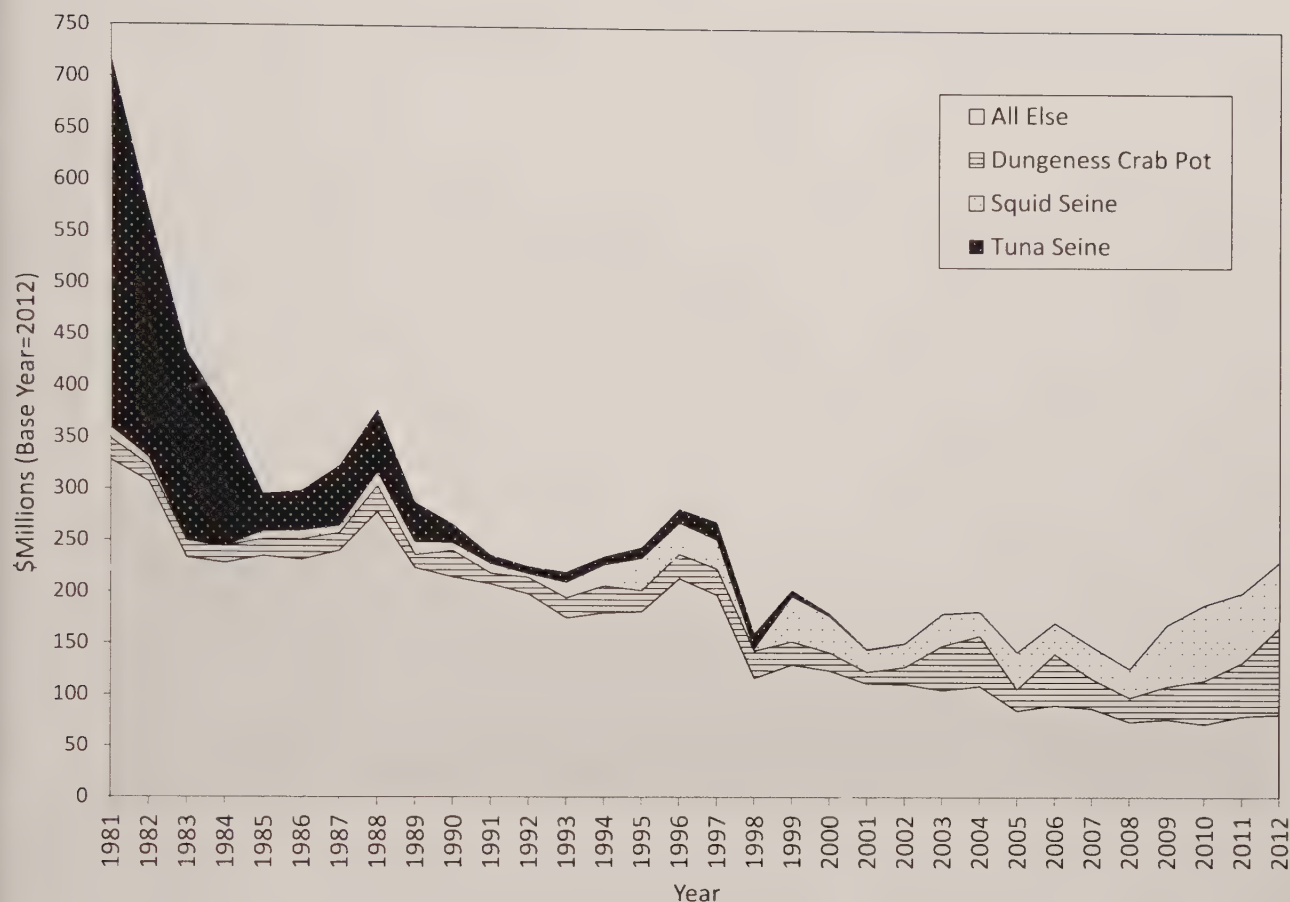


Figure 5.—Ex-vessel revenues in California commercial fisheries, including revenues in selected fisheries (tuna seine, squid seine, Dungeness crab pot), 1981–2012.

Ex-Vessel Revenues

Figure 5 depicts California ex-vessel revenues during 1981–2012. Unlike statewide participation and landings trends, which have been driven by a handful of fisheries, it is difficult to identify any specific fisheries that have consistently dominated revenues. However several fisheries (tuna seine, Dungeness crab, squid seine) have been particularly influential in certain years of the time series. Statewide revenues declined from \$634 million in 1981 to \$385 million in 1983, largely due to closure of the southern California tuna canneries. Revenues continued to fall from \$296–\$378 million in 1984–89 to \$187–\$240 million in 1990–97 to \$126–\$192 million in 1998–2010. The trend reversed in

2011–12 (\$205–\$232 million), when an upsurge in Dungeness crab and squid seine revenues caused statewide revenues to increase to levels not experienced since 1999. Since 2003, Dungeness crab pot and squid seine together have dominated statewide revenues—accounting for an average 47% of revenues during 2003–08 and 61% in 2009–12.

California fisheries exhibit a variety of revenue trends that reflect changes in landings and prices over time. Fisheries that have experienced fairly persistent revenue increases since 1981 include the following:

- Dungeness crab revenues, like landings, increased markedly in the early 2000's. Revenues increased from \$10.4–\$26.8 million in 1981–2002 to \$21.1–\$52.6 mil-

lion in 2003–11, then peaked at \$85.6 million in 2012. The ex-vessel price in 2012 (\$3.32/lb) rivaled previous highs experienced in 1983–84 (\$3.06/lb) and 2001 (\$3.23/lb). Record low salmon harvests in the late 2000's likely encouraged diversion of salmon troll effort to the Dungeness crab fishery.

- Due to the El Niño effects noted earlier, squid seine revenues (like landings) reached lows in 1983, 1984, 1992, and 1998 (\$0.6–\$3.7 million). However (excluding El Niño years), the revenue trend has been generally upward, increasing from \$7.0–\$15.1 million in 1981–93 to \$20.6–\$44.3 million in 1994–2008 to \$59.9–\$73.9 million in 2009–12. Squid prices dur-

ing 2003–12 (\$0.25–0.33/lb) were exceeded only in 1983–85 (\$0.33–0.47/lb) and 1998 (\$0.34/lb). However 1983–85 and 1998 were low years in terms of landings, while landings in the post-2003 years have been exceptionally high (including record highs of 268.0–288.4 million lb in 2010–11).

- California spiny lobster, *Panulirus interruptus*, pot revenues increased from \$3.4–4.0 million in 1981–87 to \$5.0–6.8 million in 1988–95, then increased further from \$5.7–9.1 million in 1996–2009 to \$11.8–13.7 million in 2010–12. Prices reached record highs (\$15.68–17.23/lb) in these last three years. Management measures for this fishery include limited entry, gear restrictions, size limits, and season and area closures. CDFW recently drafted the California Spiny Lobster Fishery Management Plan (CDFW⁸), which considers additional restrictions as well as modifications to current ones.

Fisheries that have experienced fairly persistent revenue decreases since 1981 include the following:

- CPS seine revenues declined from \$41.0 million in 1981 to \$20.7 million in 1984, then fell to \$5.6–19.1 million in 1985–2009 and \$5.5–5.6 million by 2010–12. The majority of CPS harvest from the early 1990's to 2012 has consisted of sardine. Factors contributing to the revenue decline in recent years include reductions in sardine stock abundance since 2007 and diversion of CPS effort to the more lucrative squid fishery.
- Non-whiting groundfish trawl revenues fell from \$31.7–40.2 million in 1981–89 to \$23.0–33.6 million in 1990–97, then declined more precipitously from \$19.3 million in 1998 to \$6.7 million in

2012. These declines are consistent with the decline in groundfish trawl landings described earlier.

- Salmon troll revenues (like landings) have been highly variable, with unpredictable river and ocean conditions contributing to the variability in landings. Probably the most notable change in management has been the adoption of restrictive weak-stock management policies since the early 1990's. Average annual revenue was \$30.9 million in 1981–90 and \$10.7 million in 1991–2007. The earlier period includes the two highest revenue years, \$45.5 million in 1987 and \$72.1 million in 1988. After the unprecedented fishery closures in 2008–09, revenue rebounded to \$12.9 million by 2012. Prices fell from \$5.54/lb in 1981 to \$1.89–2.62/lb by 1995–2003, largely due to competition from cheaper, imported Atlantic salmon (Fig. 6). The steady decline in prices exacerbated the effect of declining landings on revenues during this period. However, since 2006, salmon prices have rebounded to \$4.48–5.69/lb, partly due to development of niche markets for wild salmon and record low California harvests in the late 2000's.
- Both the tuna seine and albacore troll fisheries were affected by the southern California cannery closures in the early 1980's. Tuna seine revenues fell from \$359.0 million in 1981 to \$129.4–239.8 million in 1982–84 to \$6.5–18.7 million by 1990–99; revenues have been well below \$550,000 since 2006. Albacore troll revenues fell from \$50.3 million in 1981 to \$18.1–30.1 million in 1982–84, then \$3.0–16.4 million in 1985–2004 and \$1.0–2.6 million in 2005–12.
- Abalone, *Haliotis* spp., revenues declined from \$4.7 million in 1981 to \$1.4 million in 1997, with prices, which increased from \$3.88–4.22/lb during 1981–83 to \$12.72–13.43/lb in 1994–97, more

than offset by the decline in landings. The commercial fishery has been closed since 1998 due to low abundance variously attributed to overharvest, sea otter, *Enhydra lutris*, predation, and withering syndrome (Haaker et al., 2001).

Fisheries with revenues that peaked in the mid-1980's to early 1990's before beginning their downward trend include the following:

- Sea urchin revenues increased from \$6.9–11.1 million in 1981–85 to a peak of \$33.4–52.3 million during 1988–95, then declined to \$5.7–8.2 million by 2005–12. During 1991–94, urchin was the highest revenue fishery in California. Urchin prices increased from \$0.38–0.52/lb in 1981–87 to a peak of \$1.43–1.54/lb in 1993–95, then declined to \$0.53–0.73/lb by 2005–12. Landings peaked earlier (1986–92) than revenues (1988–95), due to the trend in prices. The decline in this fishery has been variously attributed to infrequent recruitment and intensive harvesting, particularly in northern California, and the depressed Japanese market (Kalvass and Rogers-Bennett, 2001).
- Whiting trawl revenues increased from \$0.3 million in 1981 to a peak of \$1.7–1.8 million in 1988–89, decreased to \$0.2–1.1 million during 1992–2010 and virtually disappeared in 2011–12. The recent disappearance of this fishery in California has been attributed to trading of whiting quota pounds for more lucrative species by California participants in the groundfish trawl catch share program (CDFW, 2013). Even prior to the catch share program, Oregon and Washington (where whiting processing capacity is concentrated) accounted for the vast majority of west coast whiting landings.
- Revenues in the swordfish drift gillnet fishery increased from \$4.3 million in 1981 to \$22.2 million in 1985 but declined to less than \$800,000 by 2010–12; landings exhibited a similar pattern.

⁸CDFW. 2016. Draft California spiny lobster fishery management plan. 6 Jan. 2016. Calif. Dep. Fish Wildlife, Marine Region, Monterey, Calif., 227 p. (Avail. online at http://www.fgc.ca.gov/public/notices/Lobster_Fishery_Management_Plan_010616_Draft.pdf)

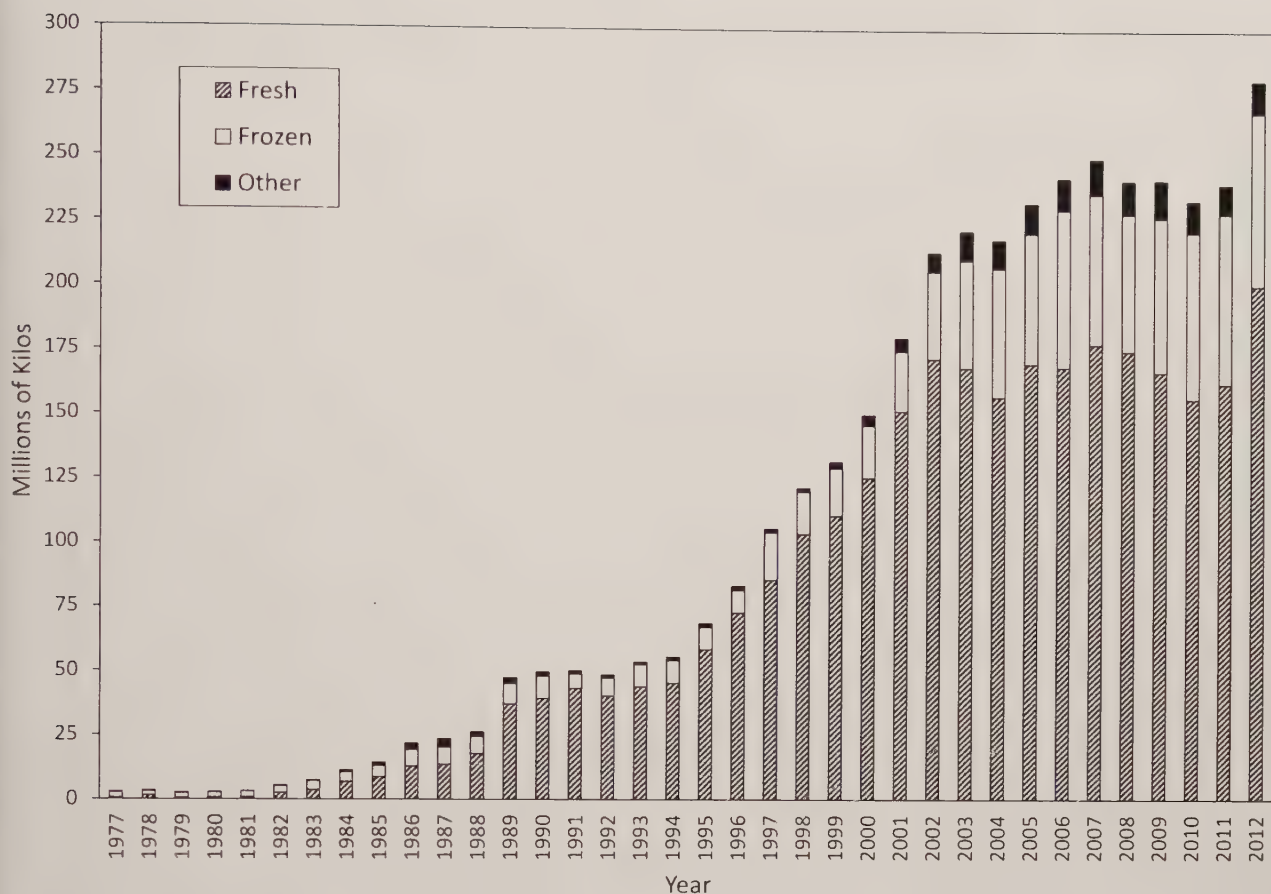


Figure 6.—U.S. salmon imports by product type (fresh, frozen, other), 1976–2012 (source: Fisheries Statistics Division, NMFS Office of Science and Technology).

Swordfish prices declined from \$4.69–7.07/lb during 1981–96 to \$2.95–4.52/lb in 1997–2012. Time and area closures implemented in 2001 by the PFMC to reduce incidental take of migratory turtles have notably diminished the fleet’s access to productive fishing grounds (PFMC, 2013b). Drift gillnet vessels are subject to other management measures such as limited entry, logbook and observer requirements, and “pingers” to deter marine mammals.

- Groundfish gillnet revenues increased from \$2.9 million in 1981 to a peak of \$8.5 million in 1986, then declined to \$4.8 million by 1990 and have been negligible since the late 1990’s. In 1990, California voters passed Propo-

sition 132, which banned the use of gillnets in state waters by 1994 (Lyons et al., 2013). This closure has been largely responsible for the reduction in nearshore gillnet activity over the past two decades.

Fisheries that did not exhibit any consistent revenue trend during 1981–2012 include the following:

- The groundfish fixed-gear fishery experienced highly variable revenues, with lows in 1984–85 and 2002–05 (\$5.5–6.5 million), and highs in 1982, 1992, 1995–97, and 2010–11 (\$13.4–17.6 million). The fixed gear fishery targets sablefish and other groundfish (mostly rockfishes). Sablefish landings declined from 6.8–8.9 million lb in 1981–83 to 1.1–1.9 million lb by 1998–2008, then increased to 2.6–

4.2 million lb in 2009–12. Near-shore rockfish landings increased from an average of 590,000 lb during 1981–90 to 1.3–1.8 million lb in 1991–98 (fueled by development of the live fish market), but have been consistently less than 600,000 lb since 2003. Other rockfish landings were 2.7–6.8 million lb during 1981–98 (except for 1992, when landings peaked at 8.5 million lb), then declined to 0.8–1.4 million lb in 1999–2012. Average prices for nearshore rockfishes (including those caught dead as well as live) increased from \$0.93/lb during 1981–85 to \$5.51/lb in 2011–12. Prices also increased over the same two periods for other rockfishes (from \$1.06 to \$2.53/lb) and sablefish (from \$0.66 to

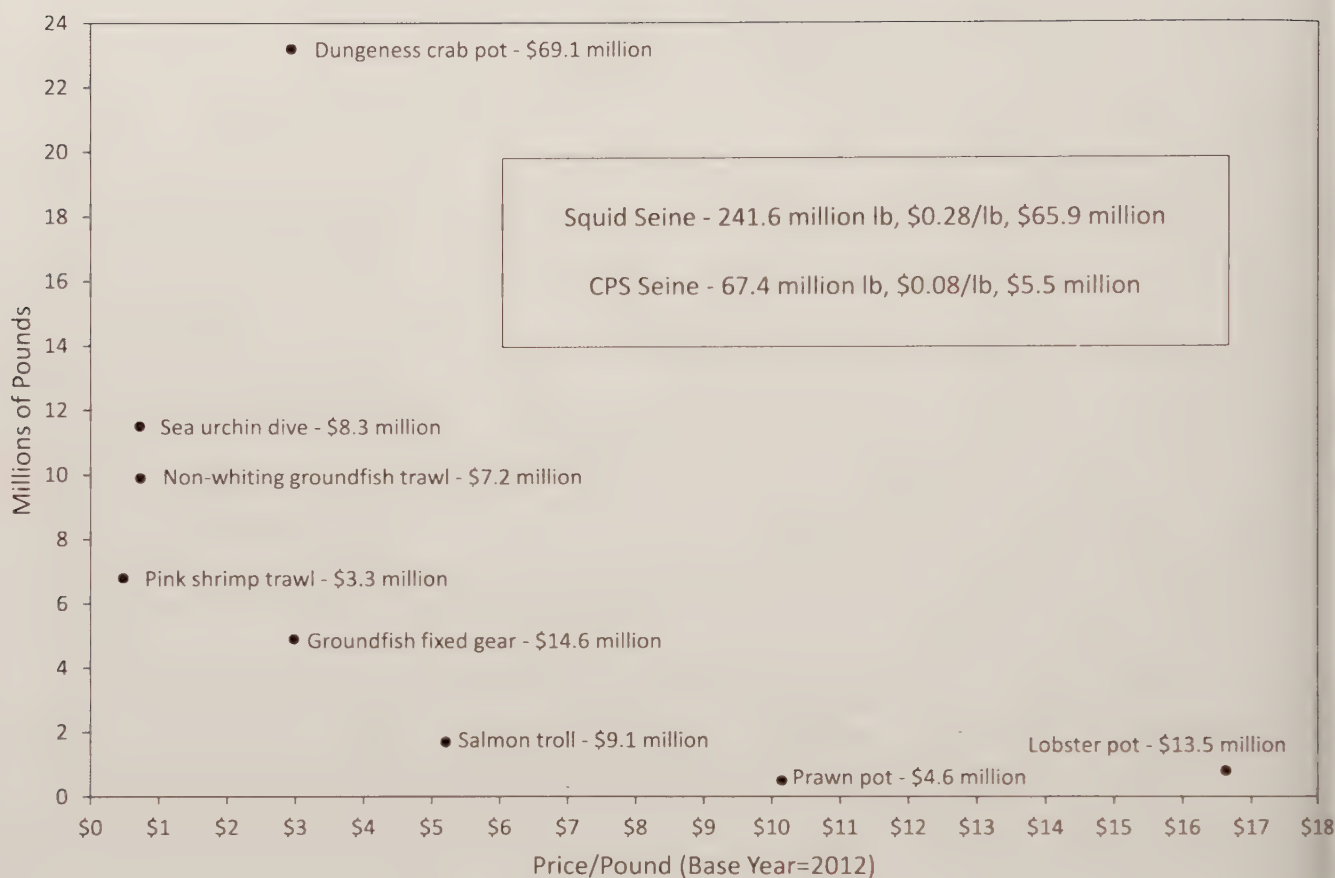


Figure 7.—Average annual landings, revenue and prices in California's top-ten revenue fisheries in 2011–12. High-volume squid seine and CPS seine fisheries noted but not graphed to better distinguish landings in other fisheries on y-axis.

\$2.81/lb). These price increases have moderated the impact of falling landings. The contributions of sablefish, nearshore rockfish, and other rockfish to total revenues averaged 38%, 25%, and 27%, respectively, during 1981–2012. The sablefish share declined from 45% during 1981–85 to a low of 12% in 1993, then increased to 65% by 2011–12. The nearshore rockfish share increased from 6% during 1981–85 to a high of 50% in 1998, then declined to 16% by 2011–12. The other rockfish share increased from 47% in 1981–85 to a high of 69% in 1989 then declined to 19% by 2011–12.

- The hagfish, *Eptatretus stoutii*, pot fishery emerged briefly in the late 1980's with landings ex-

ported for the eelskin market in the Republic of Korea. The fishery then disappeared and reemerged in 2007, with hagfish now sold in South Korea's live fish market for human consumption (CDFG, 2008:31–34). Annual revenues were \$0.6–3.6 million in 1988–90 and \$0.6–1.6 million in 2007–12.

Figure 7 depicts average annual landings, prices, and revenues in 2011–12 for the ten California fisheries that generated at least \$3 million in average annual revenue in those 2 years. The squid seine and CPS seine fisheries are noted but not graphed in Figure 7, as the magnitude of their landings (242 million and 67 million lb, respectively) would have obscured differences in landings on the y-axis

for the other eight fisheries. Figure 7 illustrates the heterogeneity of species, gear types, and price-landings combinations associated with California's highest-revenue fisheries.

Spatial Distribution of Fishing Activity

This section describes fishing activity in five designated regions—Southern California, South Central California, Central California, North Central California, and Northern California—and how activity is distributed among ports within each region (Figure 8 gives region and port locations, ignoring the numbers for now). Table 2 shows how vessel participation, landings, and revenues in each region have varied over time. Regional differences reflect the spa-

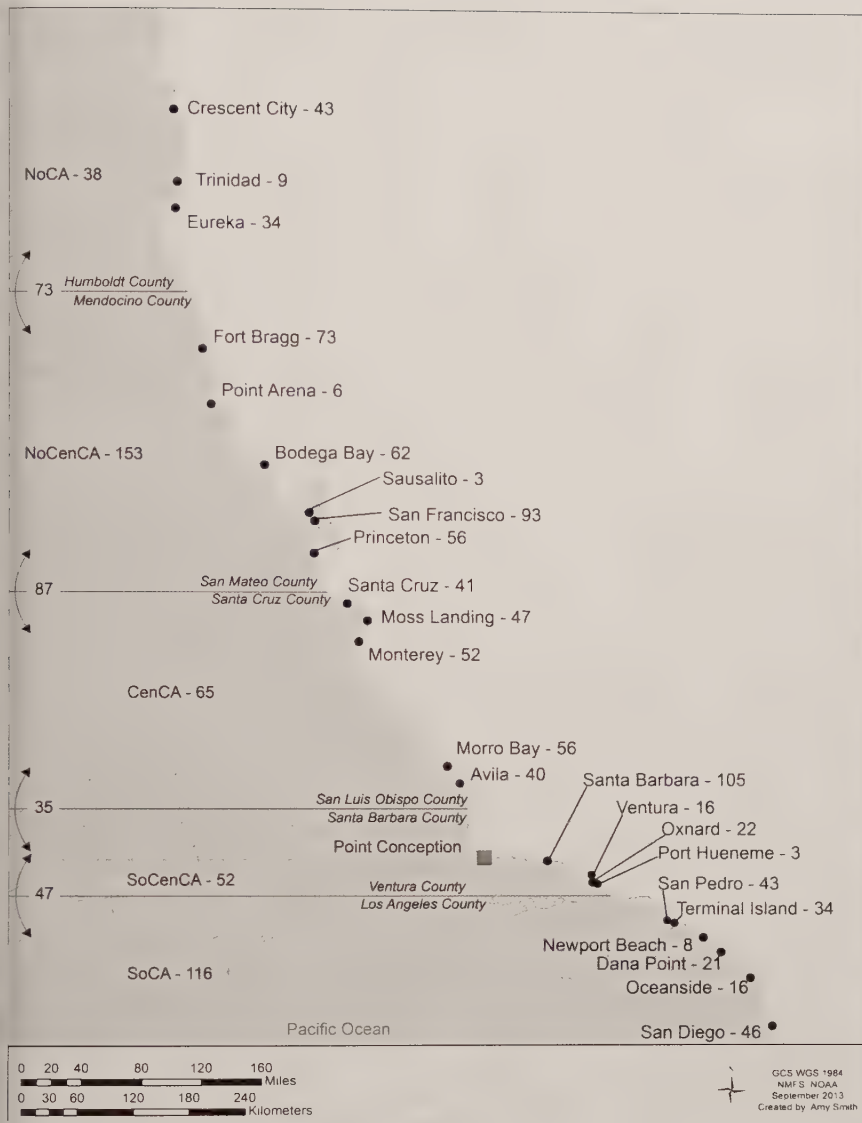


Figure 8.—Major California fishing ports by region, and average annual number of boats fishing exclusively in each port, each region, and adjacent regions, 2011–12.

Chinook) that disproportionately constrained the salmon troll fishery in that region (PFMC, 2016a).

Landings were highest in Southern California in 31 of the 32 years. This region accounted for an average 66% of statewide landings during 1981–84 and 42% in 1985–2012, largely due to the concentration of the high volume seine fisheries for tuna, squid, and CPS in this region. North Central California and Northern California were the lowest landing regions, each accounting for an average 10% of statewide landings during 1981–2012; these are the only regions that lack squid and CPS fisheries. Revenues were highest in Southern California in 21 of the 32 years, partly driven by the same seine fisheries that accounted for high landings in this region. Revenues were lowest in Central California in 21 of the 32 years (all after the late 1980's). Although Central California has a number of major fisheries in common with other regions, groundfish trawl revenues are consistently lower in this region than North Central and Northern California, salmon troll revenues are consistently lower here than North Central California, and squid seine revenues have been lower here than Southern and South Central California in most years since 1995.

For each region, Table 3 identifies fisheries that provided at least 5% of regional revenues in at least one of the designated time intervals. Some of the fisheries in Table 3 are region-specific (tuna seine in Southern California; Pacific herring, *Clupea pallasii*, net in North Central California). However, most fisheries occur in multiple regions, with one fishery (groundfish fixed gear) occurring statewide. The highest-revenue fisheries in each region in 2011–12 were squid seine in Southern and South Central California, squid seine and groundfish fixed gear in Central California, and Dungeness crab pot in North Central and Northern California. Comparison with previous time intervals indicates the fluidity of the revenue shares over time.

Figures 9a–e illustrate the port contributions to regional revenue and how

tial distribution of high-participation, high-volume, and high-revenue fisheries across the state.

Vessel participation was consistently highest in North Central California in all 32 years of the time series, with an average 42% of active vessels landing fish in this region. The majority of the salmon troll fleet is concentrated in this region as well as a sizeable number of Dungeness crab and groundfish fixed gear vessels. Vessel participation was lowest in South Central California in 12 of the 32 years (mostly from the

early 1980's to the early 1990's) and in Northern California in the other 20 years (mostly after the early 1990's). Fewer groundfish fixed gear vessels operate in South Central California than any other region, and lobster pot vessels are concentrated more in Southern California. The notable decline in participation in Northern California after the early 1990's is largely due to more restrictive regulations on Klamath River fall Chinook (the basis for NMFS' consultation standard for ESA-listed California Coastal

these contributions have changed over time.

- The highest revenue ports in Southern California are Terminal Island and San Pedro (Fig. 9a). The closure of Terminal Island and San Diego tuna canneries in the early 1980's had an immediate negative effect on San Diego's revenue share; however, non-tuna landings at Terminal Island have remained sufficiently high for that port to retain its status as a high revenue port. Revenue contributions by Oceanside, Dana Point, and Newport Beach have been much more modest but have increased over time. Some notable fisheries identified with specific ports include lobster pot in San Diego, Oceanside, and Dana Point; groundfish fixed gear in Oceanside, Dana Point, and Newport Beach; and squid seine and CPS seine in San Pedro and Terminal Island.
- In South Central California, revenue shares have generally increased for Port Hueneme and Ventura and decreased for Oxnard and Santa Barbara; however, all four ports continue to contribute substantially to regional revenue (Fig. 9b). Some notable fisheries identified with specific ports include lobster pot in Santa Barbara, squid seine in Port Hueneme and, to a lesser extent, Ventura, and groundfish fixed gear in Santa Barbara.
- In Central California, Moss Landing is the highest revenue port, followed by Morro Bay and Monterey, then Avila and Santa Cruz (Fig. 9c). Some notable fisheries identified with specific ports include Dungeness crab pot in Moss Landing and Santa Cruz, squid seine in Moss Landing and Monterey, and groundfish fixed gear in Morro Bay and, to a lesser extent, Moss Landing and Avila.
- In North Central California, the highest revenue port generally has been San Francisco, followed by Fort Bragg, then Princeton and

Table 2.—Number of boats, landings (millions of pounds), and revenue (\$millions, base year=2012), 1981–2012, by region and time interval. Number of boats not additive across regions as some boats fish in multiple regions. Statewide landings and revenues are slightly higher than sum across regions as not all landings and revenues can be attributed to a region.

	1981–2012 Avg	1981–85 Avg	1986–90 Avg	1991–95 Avg	1996–2000 Avg	2001–05 Avg	2006–10 Avg	2011–12 Avg
Southern California								
#Boats	743	1,348	928	775	642	494	408	402
Landings	194.8	360.0	207.5	130.2	190.4	144.9	148.9	162.6
Revenue	87.5	263.8	95.7	45.9	57.6	36.5	39.7	52.4
South Central California								
#Boats	469	548	581	626	488	345	295	301
Landings	80.5	41.0	58.6	72.9	125.3	76.3	99.2	105.1
Revenue	33.9	20.8	31.2	44.6	39.4	25.8	37.9	43.4
Central California								
#Boats	855	1,376	1,141	1,045	812	560	340	493
Landings	56.9	53.4	43.9	44.4	60.9	67.0	73.6	52.5
Revenue	23.7	31.1	31.5	24.7	24.0	17.9	13.5	23.2
North Central California								
#Boats	1,453	2,477	2,432	1,566	1,108	876	557	702
Landings	45.6	62.1	80.3	52.2	38.0	26.4	17.8	37.1
Revenue	49.5	59.0	75.4	52.5	44.1	34.4	26.7	61.4
Northern California								
#Boats	591	1,280	758	597	445	322	279	252
Landings	40.2	47.3	56.8	49.3	38.5	27.2	29.3	22.2
Revenue	35.4	40.5	43.2	38.1	33.1	26.8	30.0	38.0
Total California								
#Boats	3,359	5,776	4,710	3,699	2,847	2,143	1,605	1,800
Landings	418.4	564.1	447.6	349.4	453.3	342.1	369.1	380.2
Revenue	230.6	415.9	278.7	206.2	198.4	141.5	147.8	218.6

Bodega Bay (Fig. 9d). Point Arena and Sausalito once accounted for over 5% of regional revenue but have been minor ports in recent years. Some notable fisheries identified with specific ports include Dungeness crab pot in San Francisco, Bodega Bay, and Princeton; groundfish trawl in Fort Bragg; salmon troll in Fort Bragg, Bodega Bay, San Francisco and Princeton; and groundfish fixed gear in Fort Bragg.

- In Northern California, the highest revenue ports have been Crescent City and Eureka (Fig. 9e). Fields Landing's contribution to regional revenue peaked at 21% in 1985 but has been much less than 5% in recent years, while Trinidad's contribution has been low but fairly stable over time. Some notable fisheries identified with specific ports include Dungeness crab pot in Crescent City and Eureka, shrimp trawl in Crescent City, and groundfish trawl in Eureka.

California Fleet Dynamics

Figure 10 depicts the number of boats that made at least one trip in California, the number of "California

boats" (boats that derived the plurality of their revenue from California as opposed to Oregon and Washington landings), and the number of California boats whose annual revenue exceeded \$5,000. Almost all boats that land fish in California qualify as "California boats" in terms of plurality of revenue. The total number of California boats declined from 6,378 in 1981 to 1,432 in 2009, then increased to 1,809 by 2012. Following a similar pattern, the number of California boats earning more than \$5,000 declined from 3,173 in 1981 to 1,082 in 2009, then increased to 1,390 by 2012.

California boats earning less than \$5,000 comprise a substantial though declining proportion of the California fleet. Many of these vessels are salmon trollers operated by fishermen who are semi-retired or also engaged in other occupations. The proportion of California vessels earning less than \$5,000 has decreased from 50% in 1981 to 23% in 2012. This change is consistent with the precipitous decline in the number of salmon trollers over time (Fig. 2). The remainder of this section focuses on "California boats" in terms of vessel-level activity and performance.

Table 3.—Relative distribution of regional revenue among fisheries, 1981–2012, by region and time interval.

	1981–2012 Avg	1981–85 Avg	1986–90 Avg	1991–95 Avg	1996–2000 Avg	2001–05 Avg	2006–10 Avg	2011–12 Avg
Southern California								
Tuna Seine	0.24	0.67	0.43	0.19	0.20	0.02	0.01	0.00
Squid Seine	0.19	0.01	0.04	0.07	0.14	0.28	0.46	0.59
CPS Seine	0.13	0.09	0.16	0.15	0.13	0.13	0.14	0.07
Lobster Pot	0.09	0.01	0.05	0.09	0.08	0.11	0.15	0.17
Urchin Dive	0.07	0.01	0.07	0.14	0.10	0.09	0.03	0.03
Albacore Troll	0.06	0.08	0.04	0.11	0.13	0.03	0.01	0.01
Swordfish Net	0.05	0.06	0.08	0.06	0.04	0.03	0.03	0.00
Swordfish H&L/Harpoon	0.05	0.01	0.02	0.03	0.08	0.15	0.02	0.00
Groundfish Fixed Gear	0.05	0.02	0.03	0.07	0.05	0.07	0.06	0.04
Subtotal	0.93	0.96	0.92	0.91	0.95	0.91	0.91	0.91
All Else	0.07	0.04	0.08	0.09	0.05	0.09	0.09	0.09
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
South Central California								
Squid Seine	0.30	0.02	0.12	0.18	0.41	0.42	0.57	0.56
Urchin Dive	0.28	0.30	0.40	0.53	0.24	0.20	0.12	0.10
Lobster Pot	0.07	0.05	0.04	0.04	0.06	0.10	0.09	0.11
Abalone Dive	0.05	0.13	0.08	0.06	0.01	0.00	0.00	0.00
Groundfish Fixed Gear	0.04	0.04	0.04	0.05	0.05	0.03	0.02	0.05
CPS Seine	0.04	0.11	0.04	0.01	0.02	0.04	0.02	0.01
Prawn Trawl	0.03	0.05	0.02	0.02	0.08	0.03	0.02	0.01
Halibut Net/Trawl	0.02	0.05	0.03	0.01	0.02	0.02	0.01	0.01
Swordfish Net	0.02	0.07	0.03	0.01	0.00	0.00	0.00	0.00
Shark Net	0.02	0.05	0.03	0.01	0.01	0.01	0.00	0.00
Subtotal	0.87	0.87	0.83	0.92	0.90	0.85	0.85	0.89
All Else	0.13	0.13	0.17	0.08	0.10	0.15	0.15	0.11
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Central California								
Groundfish Trawl	0.17	0.21	0.23	0.25	0.20	0.13	0.06	0.05
Groundfish Fixed Gear	0.14	0.06	0.04	0.12	0.17	0.13	0.26	0.26
Squid Seine	0.14	0.12	0.07	0.14	0.06	0.27	0.13	0.31
Salmon Troll	0.14	0.13	0.23	0.16	0.14	0.14	0.03	0.09
CPS Seine	0.10	0.06	0.02	0.04	0.09	0.10	0.30	0.08
Swordfish Net	0.07	0.09	0.14	0.08	0.06	0.02	0.03	0.02
Albacore Troll	0.05	0.14	0.04	0.02	0.06	0.06	0.01	0.02
Dungeness Crab Pot	0.03	0.00	0.01	0.02	0.01	0.03	0.07	0.09
Groundfish Net	0.03	0.04	0.10	0.04	0.01	0.00	0.00	0.00
Pink Shrimp Trawl	0.02	0.01	0.00	0.03	0.08	0.02	0.00	0.00
Prawn Pot	0.02	0.00	0.00	0.01	0.02	0.04	0.06	0.04
Subtotal	0.91	0.86	0.88	0.91	0.90	0.94	0.95	0.96
All Else	0.09	0.14	0.12	0.09	0.10	0.06	0.05	0.04
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
North Central California								
Dungeness Crab Pot	0.23	0.05	0.07	0.08	0.18	0.31	0.51	0.63
Salmon Troll	0.20	0.27	0.32	0.13	0.14	0.30	0.10	0.11
Groundfish Trawl	0.17	0.27	0.17	0.20	0.19	0.12	0.15	0.04
Herring Net	0.13	0.25	0.14	0.18	0.18	0.06	0.02	0.01
Urchin Dive	0.10	0.00	0.15	0.22	0.10	0.07	0.07	0.04
Groundfish Fixed Gear	0.06	0.03	0.06	0.07	0.08	0.05	0.08	0.05
Albacore Troll	0.02	0.07	0.01	0.01	0.01	0.01	0.01	0.01
Squid Seine	0.01	0.00	0.00	0.01	0.00	0.01	0.00	0.05
Subtotal	0.92	0.94	0.92	0.90	0.88	0.93	0.94	0.94
All Else	0.08	0.06	0.08	0.10	0.12	0.07	0.06	0.06
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Northern California								
Dungeness Crab Pot	0.48	0.39	0.34	0.37	0.50	0.56	0.67	0.65
Groundfish Trawl	0.28	0.37	0.37	0.31	0.29	0.22	0.19	0.13
Pink Shrimp Trawl	0.10	0.05	0.17	0.19	0.09	0.04	0.03	0.12
Groundfish Fixed Gear	0.04	0.02	0.03	0.04	0.04	0.06	0.06	0.05
Salmon Troll	0.03	0.11	0.06	0.00	0.00	0.02	0.01	0.02
Albacore Troll	0.03	0.06	0.01	0.03	0.03	0.06	0.02	0.02
Swordfish Net	0.01	0.00	0.00	0.05	0.01	0.00	0.00	0.00
Subtotal	0.97	1.00	0.98	0.99	0.96	0.96	0.98	0.99
All Else	0.03	0.00	0.02	0.01	0.04	0.04	0.02	0.01
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

increased to new highs in 2009–12 (\$115,000–129,000). The increasing revenue trend reflects the effects of greater opportunity in some fisheries as well as the exit of lower-revenue vessels over time.⁹

Vessel Behavior by Region

Table 4 describes California vessels by “principal region” (i.e., the region accounting for the plurality of the vessel’s annual revenue) in terms of average annual number of vessels and average annual trips, landings, and revenues per vessel. Regional boundaries are the same as shown in Figure 8. Participation is consistently higher for North Central California than other regions, largely due to the concentration of salmon trollers in that region. Landings and revenue per vessel are influenced by the number of vessels in each region that participate in high-volume and high-revenue fisheries. Thus, for instance, high landings per boat in Southern and South Central California are affected by the concentration of CPS and squid seiners in these regions. Revenue per boat has generally been higher in 2006–10 and 2011–12 than in previous time intervals in all regions except Southern California. Due to the dominance of the tuna seine fishery in Southern California in the early 1980’s, revenue per boat in that region was much higher in 1981–85 than in subsequent years.

Geographic Mobility and Fishery Diversification

Geographic mobility and fishery diversification are important risk reduction strategies (Kasperski and Holland, 2013) and reflect the ability of vessels to adapt to restrictions in a particular area or fishery (Mason et al., 2012). Geographic mobility is characterized here in terms of whether each California vessel earned all of its annual revenue in 1) a single California port, 2)

⁹Although economic profit or net revenue per vessel are more meaningful indicators of economic benefits to the fleet than gross revenues, such indicators are not provided here due to the lack of cost data for most of the fisheries covered in this paper.

Vessel Participation and Revenue

Trends in annual revenue per vessel for California vessels are depicted in Figure 11. Revenue per vessel is characterized in terms of mean and 25th, 50th (median), and 75th percentile values. The skewness of the distribution is reflected in the difference

between the mean and median values and the close coincidence of the mean and 75th percentile values. Median revenue increased from \$4,900 in 1981 to \$32,600 in 2012. Mean revenue declined from \$98,000 in 1981 to \$51,000 in 1985, largely due to the departure of tuna super seiners earning multi-million dollar revenues, and

more than one port but a single region, 3) two adjacent regions, or 4) more dispersed areas—i.e., two non-adjacent regions or more than two regions, including out of state. The relative distribution of vessels across mobility categories has remained fairly constant over time, averaging 58%, 22%, 14%, and 6% during 1981–2012 for categories 1 through 4, respectively. Figure 12 describes trends in average annual revenue per vessel for each mobility category during 1981–2012. Comparisons of revenue per vessel across mobility categories suggest that geographic mobility generally tends to enhance revenue opportunities. Average revenue does not exhibit any particular pattern over time for vessels in mobility categories 1 and 2 but has increased significantly over time for vessels in mobility categories 3 and 4.

Figure 8 depicts the geographic distribution of California vessels in mobility categories 1 through 3 during 2011–12. The number next to each port pertains to the average annual number of boats who fished exclusively in that port in 2011–12, the number next to each region pertains to the number of vessels that fished in multiple ports but exclusively in that region, and the numbers connecting adjacent regions pertain to the number of boats who fished exclusively in the two connected regions. Only mobility categories involving at least three vessels are depicted.

Fishery diversification is analyzed in terms of whether each vessel earned all of its annual revenue in one fishery, two fisheries, or more than two fisheries. The percent of vessels falling in each diversification category during 1981–2012 was 50–63% for one fishery, 23–31% for two fisheries, and 10–23% for more than two fisheries. Figure 13 describes trends in average annual revenue per vessel for each diversification category during 1981–2012.

Generally speaking, diversification tends to enhance revenue opportunities. One notable exception: vessels that participated in two fisheries during 2006–10 and 2011–12 tended on aver-

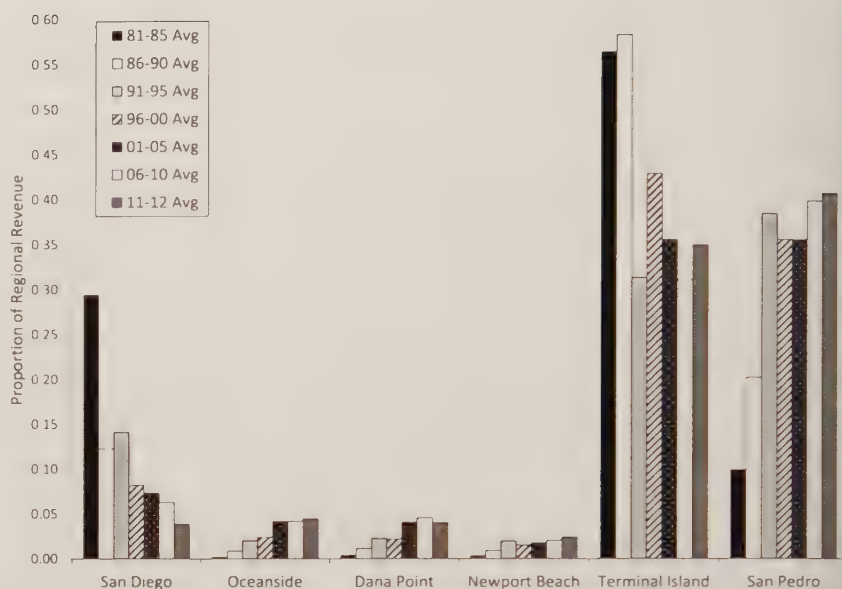


Figure 9a.—Average annual distribution of Southern California fishery revenues among ports (San Diego, Oceanside, Dana Point, Newport Beach, Terminal Island, San Pedro), 1981–2012 by time interval.

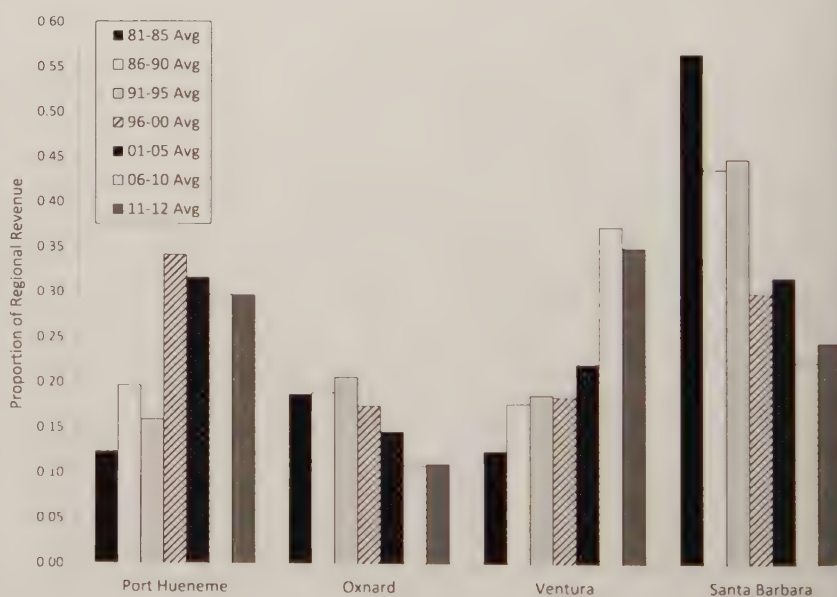


Figure 9b.—Average annual distribution of South Central California fishery revenues among ports (Port Hueneme, Oxnard, Ventura, Santa Barbara), 1981–2012 by time interval.

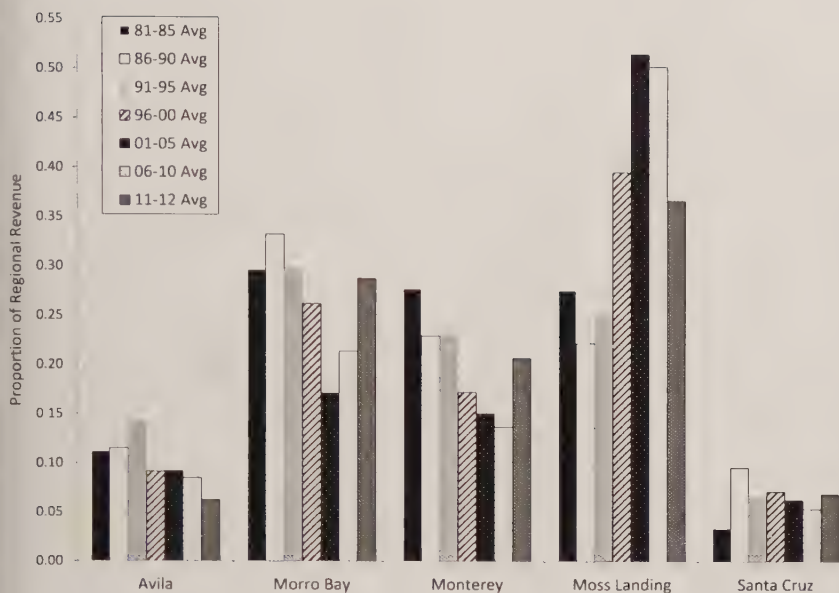


Figure 9c.—Average annual distribution of Central California fishery revenues among ports (Avila, Morro Bay, Monterey, Moss Landing, Santa Cruz), 1981–2012 by time interval.

age to have higher revenues than vessels who participated in more than two fisheries. The proportion of two-fishery vessels earning less than \$25,000 fell from 49% during 1981–2005 to 34% during 2005–12, while the proportion earning more than \$500,000 per year more than tripled from 3% to 10%. For vessels that participated in more than two fisheries, the proportion earning less than \$25,000 and more than \$500,000 moved in the same direction as the two-fishery vessels, but the change between periods consisted of only a few percentage points.

For the two most recent years, 2011–12, an average annual 1,733 vessels earned the plurality of their revenue from California landings. Of these vessels, 51% participated in one fishery, 31% in two fisheries, and 18% in more than two fisheries. Figure 14 highlights the most common one- and two-way fishery combinations employed by California vessels. The number in each box is the average annual number of boats who fished exclusively in that fishery in 2011–12, and the number connecting any two boxes is the average annual number of boats who fished exclusively in the two paired fisheries.

Table 5 highlights the most common (>3 boats) three-way fishery combinations pursued by California vessels in 2011–12. Diversification most commonly involves fisheries utilizing the same gear or combinations of line and pot gear. Salmon troll, groundfish fixed gear, and Dungeness crab pot are particularly notable—not only in terms of the number of vessels that participate exclusively in each of these fisheries but also the frequency with which they are pursued in combination with other fisheries.

Table 6 focuses on California vessels whose principal fishery was Dungeness crab pot, salmon troll, groundfish fixed gear, lobster pot, urchin dive, or squid seine in 2011 and/or 2012. “Principal fishery” is defined here as the fishery accounting for the plurality of the vessel’s annual revenue. The principal fisheries included here are those accounting for the largest number of

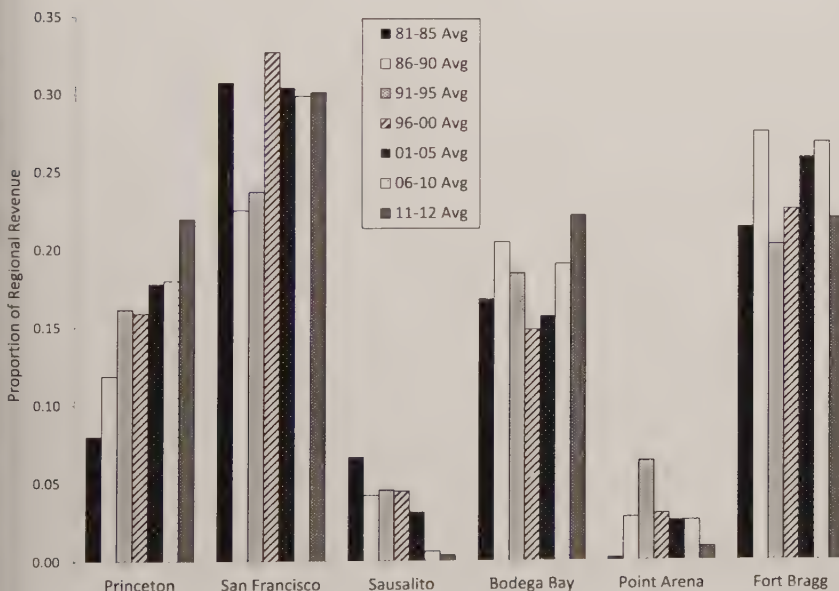


Figure 9d.—Average annual distribution of North Central California fishery revenues among ports (Princeton, San Francisco, Sausalito, Bodega Bay, Point Arena, Fort Bragg), 1981–2012 by time interval.

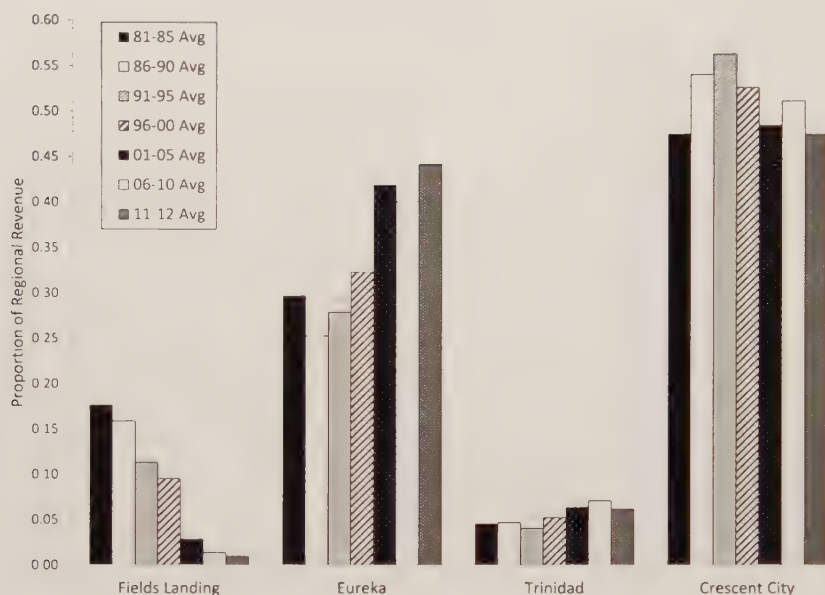


Figure 9e.—Average annual distribution of Northern California fishery revenues among ports (Fields Landing, Eureka, Trinidad, Crescent City), 1981–2012 by time interval.

boats in 2011–12. Table 6 describes the average annual number of boats associated with each principal fishery, mean and median revenue per boat, and the relative distribution of boats among geographic and fishery diversification categories. Revenue per boat pertains to the boat's earnings in all fisheries (not just its principal fishery). Revenue is highest for boats whose principal fishery is squid seine or Dungeness crab pot and lowest for salmon troll and groundfish fixed gear. Affinity for a single port or a single fishery is strongest for boats whose principal fishery is groundfish fixed gear or urchin dive, while fishery diversification is highest for Dungeness crab pot. It is important to note that Table 6 focuses only on two recent years and that revenue and diversification patterns have changed over time. For example, the proportion of one-port vessels whose

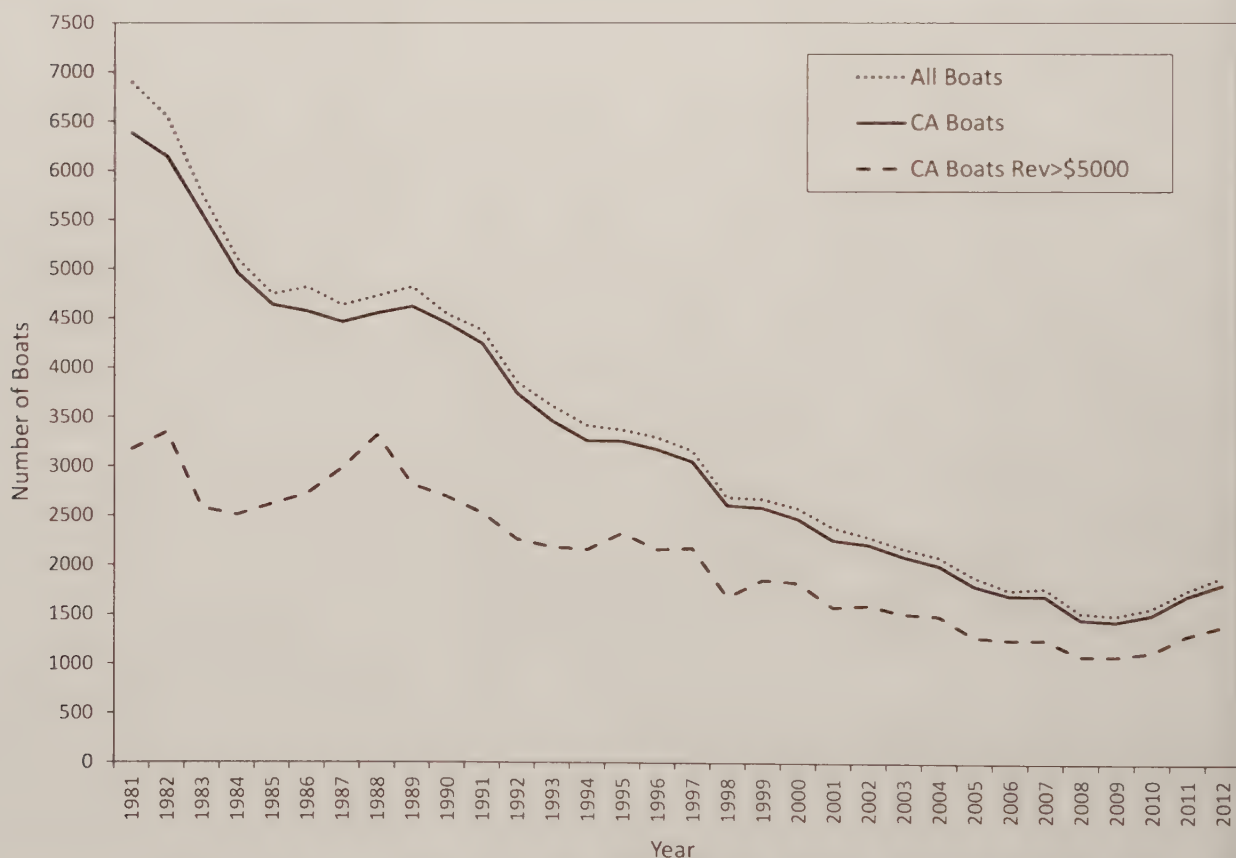


Figure 10.—Number of boats that participated in California fisheries (all boats), number of boats that earned the plurality of their revenue from California fisheries (CA Boats), and number of California boats that earned at least \$5,000 in annual revenue (CA Boats Rev > \$5,000), 1981–2012.

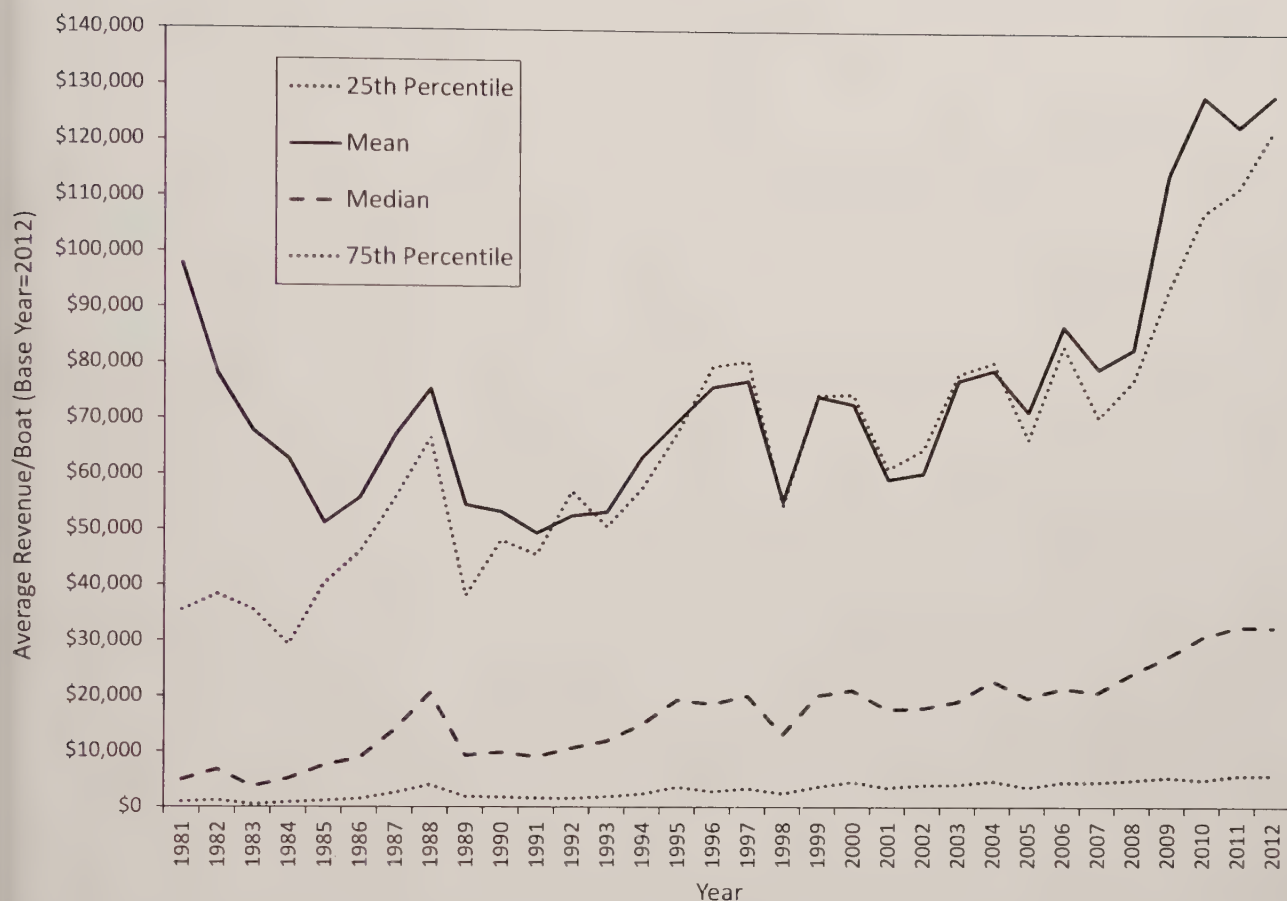


Figure 11.—Annual revenue per boat for California boats—mean, median, and 25th and 75th percentile values, 1981–2012. “California boats” are boats that earned the plurality of their annual revenue from California fisheries.

Table 4.—Number of boats and average annual trips, landings (1,000s of pounds landed weight) and revenue (\$1,000s, base year=2012) per boat, 1981–2012, by principal region¹ and time interval.

	1981–2012 Avg	1981–85 Avg	1986–90 Avg	1991–95 Avg	1996–2000 Avg	2001–05 Avg	2006–10 Avg	2011–12 Avg
Southern California								
#Boats	631	1,163	761	628	546	438	360	358
Trips/Boat	35	21	30	34	38	41	41	43
Landings/Boat	345	302	274	219	365	361	467	553
Revenue/Boat	127	218	126	76	111	92	122	171
South Central California								
#Boats	355	406	416	467	375	261	247	249
Trips/Boat	41	30	36	40	42	48	46	44
Landings/Boat	309	99	146	149	370	425	567	560
Revenue/Boat	107	52	78	97	109	107	167	188
Central California								
#Boats	629	965	839	798	598	415	260	379
Trips/Boat	24	19	25	24	26	24	26	27
Landings/Boat	114	59	55	61	91	161	258	115
Revenue/Boat	44	32	40	34	44	47	56	62
North Central California								
#Boats	1,238	2,108	2,059	1,304	944	770	492	622
Trips/Boat	22	17	23	23	24	23	22	23
Landings/Boat	48	32	42	53	62	47	44	71
Revenue/Boat	52	29	42	45	52	53	65	116
Northern California								
#Boats	506	1,134	636	502	383	258	247	192
Trips/Boat	28	25	30	28	30	29	29	28
Landings/Boat	147	58	111	139	158	182	222	173
Revenue/Boat	116	52	93	104	108	132	159	236

¹ “Principal region” defined as the region accounting for the plurality of a boat’s annual revenue.

principal fishery was salmon troll was considerably higher in 1981–83 (52%) than 2011–12 (14%), a trend related to the exit of many vessels from that fishery. The Dungeness crab fishery experienced record high revenues in 2012, and squid revenues in 2011–12 were exceeded only in 2010.

Geographic and fishery diversification are affected by a variety of factors, including the spatial distribution of target species, prices and constraints on entry in alternative fisheries, location of processors and other fishery-related businesses, fuel costs, vessel seaworthiness, ability of vessel and crew to adapt to alternative fisheries, regulations, and personal preference. The relatively low revenues earned by salmon trollers and groundfish fixed gear boats suggest that fishing is not

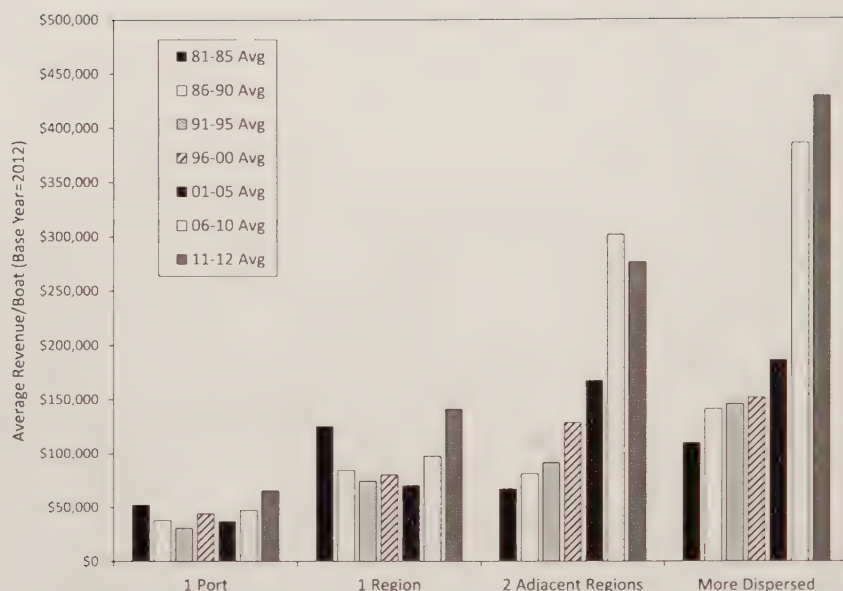


Figure 12.—Average annual revenue per boat for California boats, 1981–2012, by geographic mobility category and time interval. Mobility categories (based on regions described in Figure 8): 1 Port=landings occurred exclusively in one port, 1 Region=landings occurred in multiple ports in a single region, 2 Adjacent Regions=landings occurred exclusively in two adjacent regions, and More Dispersed=landings dispersed between two non-adjacent regions or more than two regions, including out of state.

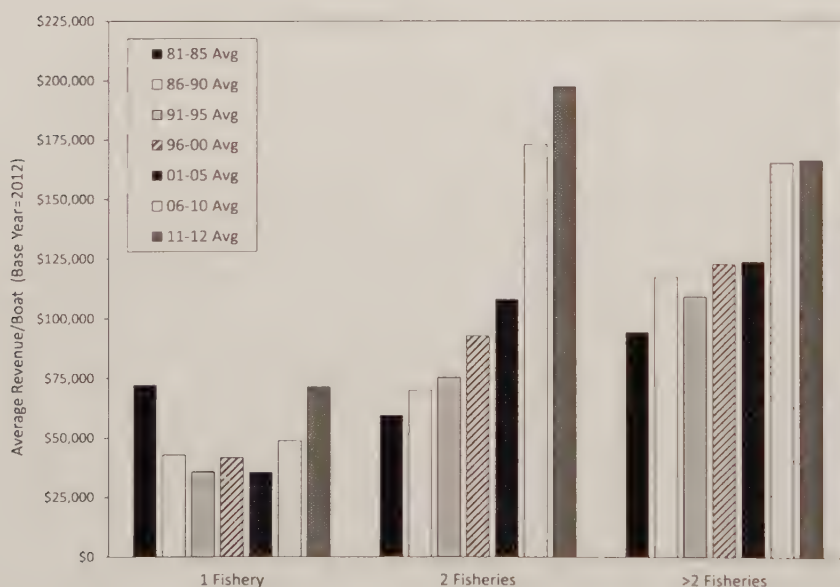


Figure 13.—Average annual revenue per boat for California boats, 1981–2012, by fishery diversification category and time interval. Fishery diversification categories (1, 2, >2) pertain to the number of fisheries in which a vessel participated during the year.

the only source of income for many of these boats; however, the extent of their non-fishing income is not known.

Conclusions

Trends in California vessel participation, landings, and revenues vary—depending on the particular fishery, time frame, and geographic area considered. For instance, the statewide landings trend dating from 1981 indicates that landings peaked in the early 1980's and have been considerably lower (though quite variable) in subsequent years (Fig. 4). By contrast, the landings trend dating from 1916 suggests even greater variability in landings and a much larger decline in recent years relative to the earlier years of that time series (Fig. 1).

Expansions and contractions of seafood markets (global as well as domestic) provide new opportunities and vulnerabilities for California fisheries. Changes in ex-vessel prices experienced in recent decades (e.g., positive for groundfish fixed gear, lobster pot, and salmon troll, negative for swordfish drift gillnet and sea urchin) and the recent reemergence of the hagfish pot fishery illustrate the influence of market conditions on fisheries. Factors such as technology, fuel prices, fishery infrastructure, labor availability, and regulatory compliance costs have also changed over time.

Past trends can provide clues to the future. However, historic lows (e.g., 1950's collapse of the sardine fishery, 2008–10 salmon landings) and highs (e.g., 1988 salmon landings, 2011–12 Dungeness crab and squid landings) do not always serve as relevant reference points for identifying current management problems or shaping expectations regarding long-term harvest opportunities. For many fisheries, regulations have become much more constraining on harvest and effort in recent decades. Harvests also vary for reasons beyond the control of managers. Environmental conditions can affect stock abundance and distribution in sometimes pronounced ways; notable examples of this have become apparent even in the few years since 2012

(the last year of the quantitative analysis provided in this paper).¹⁰ Research that systematically considers physical, biological, and economic factors in an ecosystem framework (Field et al., 2006; Norton et al., 2013) is important for understanding the complexity and interrelatedness of California fisheries.

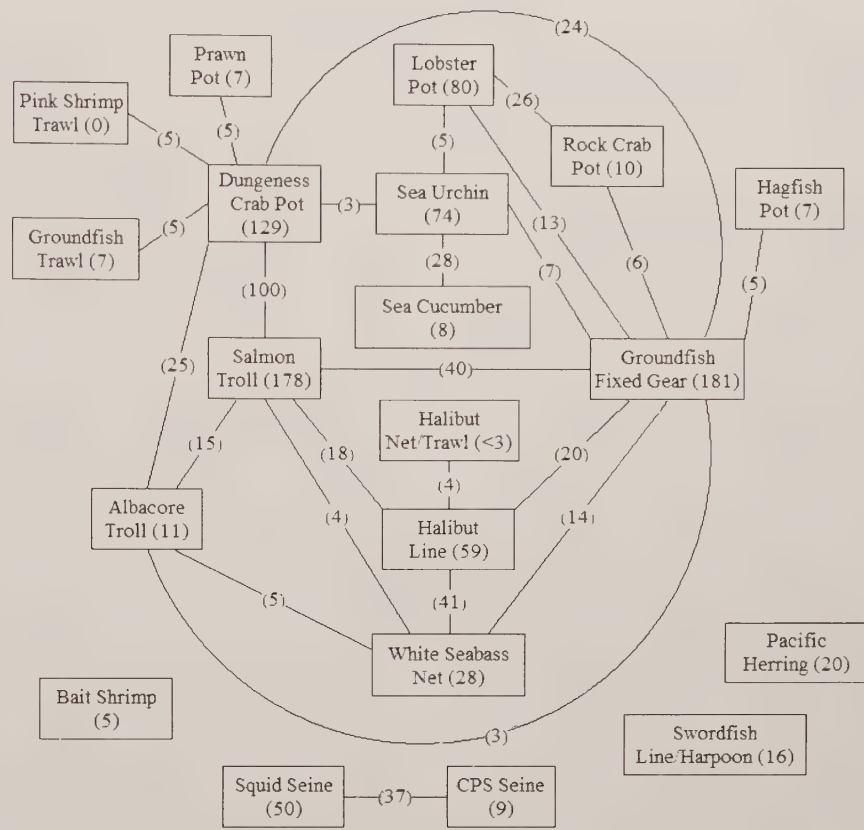


Figure 14.—Average annual number of California boats participating in most common one- and two-way fishery combinations, 2011–12.

The salmon troll fishery rebounded in 2013, with landings at 2005 levels and revenues the second highest experienced since 1990. However, persistent drought conditions and associated concerns regarding the status of endangered Sacramento River winter Chinook have since constrained the fishery (CDFW, 2015).

Evidence from California fisheries suggests that fishery diversification and geographic mobility enhance revenue. One way to encourage such flexibility would be to provide fishermen with greater operational discretion within the confines of management objectives. This may involve, for instance, tailoring regulations so that they do not unduly constrain fleet mobility or industry efforts at gear and product innovation, or making per-

Table 5.—Most common (>3 boats) three-way fishery combinations employed by California boats in 2011–12 and average annual number of boats employing each combination.

Table 6.—Number of California boats by principal fishery¹, mean and median revenue per boat from all fisheries (\$1,000s, base year=2012), and relative distribution of boats among geographic and fishery diversification categories, 2011–12 average. Principal fisheries selected for inclusion in this table are those accounting for the largest number of boats in 2011–12.

	All boats	Dungeness crab pot	Salmon troll	Groundfish fixed gear	Lobster pot	Urchin dive	Squid seine
# boats	1,751	381	288	272	159	104	100
Mean revenue	126.0	198.4	19.5	46.3	91.0	81.0	733.1
Median revenue	32.6	123.4	9.3	17.7	71.4	53.4	539.2
Vessel distribution across geographic diversification categories ²							
1 port	0.58	0.51	0.57	0.73	0.53	0.68	0.37
1 region	0.24	0.28	0.17	0.18	0.42	0.26	0.13
2 adjacent regions	0.14	0.18	0.22	0.06	0.03	0.03	0.31
More dispersed	0.04	0.03	0.04	0.03	0.02	0.03	0.19
Vessel distribution across fishery diversification categories ³							
1 fishery	0.52	0.34	0.62	0.68	0.50	0.70	0.50
2 fisheries	0.30	0.39	0.22	0.21	0.29	0.26	0.43
>2 fisheries	0.18	0.27	0.16	0.11	0.21	0.04	0.07

¹ "Principal fishery" defined as the fishery accounting for the plurality of a boat's annual revenue.

² Based on ports and regions depicted in Figure 8: 1 Port=landings occurred exclusively in one port, 1 Region=landings occurred in multiple ports in a single region, 2 Adjacent Regions=landings occurred exclusively in two adjacent regions.

³ Fishery diversification categories (1, 2, >2) pertain to the number of fisheries in which a boat participated during the year.

infrastructure needs. Understanding community dynamics requires a better understanding of the port choices made by fishermen and infrastructure providers (including processors), the extent to which fisheries contribute to port revenues and costs, and strategies used by ports to cope with variability in fishing activity.

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mit programs flexible in ways that encourage entry of “new blood” into fisheries.

Another management tool that can increase operational flexibility is catch shares. Catch share programs are well known for curtailing the race for fish and enhancing the economic productivity of quota holders (Mamula and Collier, 2015); catch shares also encourage fleet consolidation which, in turn, leads to employment losses (Lian et al., 2009). An important consideration is finding an acceptable balance between efficiency gains and employment losses. Management measures often involve such trade-offs; there is rarely a universally “best” way to achieve any given management objective (Melnichuk et al., 2013).

Given the disparate distribution of vessels, landings, and revenues among fisheries, the effect of regulations on each of these indicators can vary widely—depending on which fisheries are targeted by such regulations. Patterns of movement among fisheries are instructive for anticipating the extent to which effort displaced from one fishery (whether due to management restrictions or adverse market or environmental conditions) is diverted to other fisheries. The distinctively regional nature of many California fisheries, the high proportion of vessels that land fish exclusively in one port (58%) and one region (22%) per year, and the high dependence on lo-

cal fishery infrastructure that can be inferred from such behavior illustrates the need to consider community as well as statewide effects in evaluating management alternatives. Additional research is needed to better understand how fishery regulations and fishing behavior affect communities (Speir et al., 2014).

While a large proportion of California vessels fish in a single port, the extent to which such behavior is due to personal preference or to management or other constraints is not clear. The modest revenue earned by many of these boats (largely salmon trollers and groundfish fixed gear vessels) suggests that they may also have non-fishing income that buffers them against the vagaries of limited mobility. Landings and revenues tend to be considerably higher for more mobile operators—suggesting that they are more reliant on fishing as their major source of income.

Participation, landings, and revenue vary not only over time but also among regions (Table 2) and among ports within each region (Fig. 9a–e)—reflecting localized differences in factors such as species availability, regulations, fishery infrastructure, and weather. To the extent that high-effort or high-volume fisheries influence the location of processing plants and other infrastructure, the presence of such fisheries in a port may also benefit smaller fisheries that have similar

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A Socioeconomic Evaluation of a Network of Deepwater Marine Protected Areas

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Introduction

As defined by Marine Protected Areas Executive Order 13158, a marine protected area (MPA) is "any area of the marine environment that has been reserved by Federal, State, territorial, tribal, or local laws or regulations to provide lasting protection for part or all of the natural and cultural resources therein" (EOP, 2000).

The South Atlantic Fishery Management Council (Council) is responsible for the conservation and management of fish stocks within the Federal Exclusive Economic Zone (EEZ) off the southeastern U.S. coast. The EEZ begins 3 nmi off the coasts of North Carolina, South Carolina, Georgia, and the east coast of Florida, including the

Florida Keys, and extends offshore to 200 nmi.¹ The Council further defines MPA's within its jurisdiction as "a network of specific areas of marine environments reserved and managed for the primary purpose of aiding in the recovery of overfished stocks and to ensure the persistence of healthy fish stocks, fisheries, and associated habitats. Such areas may include naturally occurring or artificial bottom and water column habitats, and may include prohibition of harvest on seasonal or permanent time periods to achieve desired fishery conservation and management goals."²

As part of the federal regulatory process when establishing MPA's in the U.S. EEZ, the net socioeconomic impact to fishery stakeholders must be valued *ex ante*, using the best scientific information available (NOAA, 2009). In this study, we evaluate net socioeconomic impact with a traditional benefit-cost framework in which the potential benefits of protection are compared to the potential costs when evaluated over different time frames. Effects in the form of socioeconomic benefits (i.e., advantages) and costs (i.e., disadvantages) are expected to

arise due to the implementation of a network of MPA's.

The collective of these negative and positive forces and their relative influence over time result in a net socioeconomic impact to fishery stakeholders. In many instances these concepts are very hard to define and should be viewed as positive or negative effects with varying and unknown degrees of influence on an overall prediction of net socioeconomic impact associated with a particular MPA alternative

This study presents a Delphi³ approach that engages stakeholders in the public domain and produces semi-quantitative forecasts of the type and incidence of socioeconomic effects, associated with implementing a network of Type 2 MPA's⁴ in the deepwater component of the snapper-grouper (SG) fishery in the EEZ off the southeastern U.S. coast. The cumulative weighted influence of these socioeconomic effects results in a net socioeconomic impact to fishery stakeholders. The Delphi method employed in this study quantifies this impact and allows comparison of alternative MPA sites based on the resulting metric.

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¹Outer boundaries of the U.S. EEZ off the southeastern coast vary according to areas where jurisdictional boundaries meet with Bermuda, the Bahamas, and Cuba.

²Available online at <http://safmc.net/managed-areas/marine-protected-areas>.

³See Linstone and Turoff (1975) for a seminal discussion of the Delphi technique and applications.

⁴A Type 2 MPA allows some level of fishing effort within the protected areas.

ABSTRACT—Marine protected areas (MPA's) are spatially defined fishery management strategies designed to allow overfished species to recover by excluding fishing effort from certain fishing grounds and essential habitats. When MPA's are established in federal waters, the net socioeconomic im-

act to fishery stakeholders must be forecast. In many cases, conducting a quantitative impact analysis is not possible due to poor spatial resolution of available data. This study implements a semi-quantitative impact assessment based on Delphi methodology to evaluate the net socioeconomic impact

of alternative MPA sites proposed for the deepwater component of the snapper-grouper fishery off the southeastern coast of the United States. The results suggest that the approach is tractable and useful to fishery managers when assessing alternative MPA sites in a data-poor environment.

The Council implemented its "Fishery Management Plan for the Snapper-Grouper Fishery of the South Atlantic Region" to protect SG resources, which generally are site-specific, relatively long-lived, slow-growing, and vulnerable to depletion (SAFMC, 1983).⁵ The Council first investigated the potential of MPA's to protect SG species through its Snapper-Grouper Plan Development Team (PDT, 1990). Over the next decade, the Council initiated public scoping meetings and a scientific review of the 1990 PDT report, while also establishing the Experimental Oculina Research Reserve off Ft. Pierce, Fla., and implementing MPA's associated with the Florida Keys Marine Sanctuary.

In 2000, the Council began discussions regarding implementation of MPA's from North Carolina to the Florida Keys to protect deepwater species susceptible to overfishing (i.e., speckled hind, *Epinephelus drummondhayi*; golden tilefish, *Lopholatilus chamaeleonticeps*; blueline tilefish, *Caulolatilus microps*; snowy grouper, *Hyporthodus niveatus*; Warsaw grouper, *Hyporthodus nigrurus*; misty grouper, *Hyporthodus mystacinus*; and yellowedge grouper, *Hyporthodus flavolimbatus*). The process culminated in the development of Amendment 14 to the Snapper-Grouper FMP.⁶ This amendment augments traditional methods of management with permanently closed Type 2 MPA's in an effort to improve the biological health of SG deepwater resources and mitigate negative socioeconomic consequences resulting from spatial closures.⁷

⁵The Snapper-Grouper Management Complex is composed of ten species units: groupers, *Epinephelidae*; grunts, *Haemulidae*; jacks, *Carangidae*; porgies, *Sparidae*; sea basses, *Serranidae*; snappers, *Lutjanidae*; spade-fishes, *Ephippidae*; tilefishes, *Malacanthidae*; triggerfishes, *Balistidae*; and wrasses, *Labridae*.

⁶Amendment 14 (see Appendix E for the complete Delphi report) was adopted and published in the Federal Register on 13 January 2009 and available online as of 1 March 2009 at http://www.safmc.net/Library/pdf/FinalAmend14_071807.pdf.

⁷Within the Type 2 MPA's, fishing for any snapper-grouper species is not allowed. Vessels may transit through the MPA's with snapper-grouper species onboard, but fishing gear must be appropri-

Table 1.—Proposed Amendment 14 MPA's off the Carolinas and Georgia.

MPA	Location and description
Snowy Grouper Wreck	Two alternatives, 10 nmi × 15 nmi each, located 55 nmi SE of Southport, N.C. Both sited on a known snowy grouper aggregation. Alternative 1 may protect more mid-shelf species than Alternative 2.
Northern South Carolina	Three alternatives, 5 nmi × 10 nmi each, located 55 nmi SE of Murrells Inlet, S.C. All three sited on an area of low relief containing significant hardbottom. All three sited on shelf edge which is a popular spot for deepwater and mid-shelf SG species.
Edisto	Two alternatives, 5 nmi × 10 nmi each, located 45 nmi SE of Charleston, S.C. Both sited in an area of upwelling holding snowy grouper and speckled hind. Both sited on shelf edge which is a popular spot for deepwater and mid-shelf SG species.
Charleston Deep Reef	One alternative, 3.5 nmi × 6 nmi, located 50 nmi E of Charleston Harbor, S.C. Artificial reef MPA to study effects associated with implementation of MPA's sited in a depth range preferred by deepwater SG species.
Georgia	Two alternatives, 10 nmi × 10 nmi each, located 65–69 nmi SE off the mouth of Wassaw Sound, Ga. Both sited on known golden tilefish habitat and active trolling grounds for pelagic species.

Descriptions of the proposed MPA's were developed based on the Council's Public Hearing Draft for Amendment 14, published research, and expert testimony (Tables 1, 2). Several alternate locations were considered for many of the proposed MPA's. Amendment 14 proposed five MPA's off the coasts of North Carolina, South Carolina, and Georgia: Snowy Grouper Wreck, Northern South Carolina, Edisto, Charleston Deep Artificial Reef, and Georgia (Table 1; Fig. 1). Three MPA's were proposed off the Florida coast: North Florida, St. Lucie Hump, and East Hump/Unnamed Hump (Table 2; Fig. 2). Each proposed MPA also included a no-action alternative, omitted from the descriptions in the tables.

Empirical data, such as logbook trip reports, are typically used to conduct quantitative analyses of the socioeconomic impacts generated by fishery management actions in the SG fishery. However, these data are reported at a larger spatial scale than that of the MPA sites proposed in Amendment 14. It was therefore not possible to construct the needed data for a quantitative analysis to assess the socioeconomic effects that may arise due to the implementation of the proposed MPA's. As a result, a Delphi approach was adopted to develop a semi-quantitative ranking

privately stowed. Shark bottom longline gear is not allowed. Trolling for pelagic species, such as tuna, dolphin, mackerel, and billfish, is allowed within the MPA's.

system for forecasting the type and extent of socioeconomic effects that might result. The Delphi approach uses the magnitude of these effects to compute a net socioeconomic impact to fishery stakeholders which is comparable across alternative sites of the proposed MPA network.

Forecasting Net Socioeconomic Impact

The Delphi Method

The Delphi method involves repetitive response, discussion, and judgment among a panel of diverse experts and aims to result in sound collective opinion. Experts participate in a structured forum of communication so that they may systematically address a complex social problem where relevant empirical data are lacking, eventually making forecasts and sometimes supporting policy decisions (Linstone and Turoff, 1975).

Since the first applications sponsored by the U.S. Air Force and carried out at the RAND Corporation⁸ in the post-World War II era, the Delphi method has evolved; however, core traits have remained intact. Foremost, individual responses are summarized and presented back to the panel, enabling the experts to review all responses and clarify or change their own position based on their perception of the collective views of the panel.

⁸Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

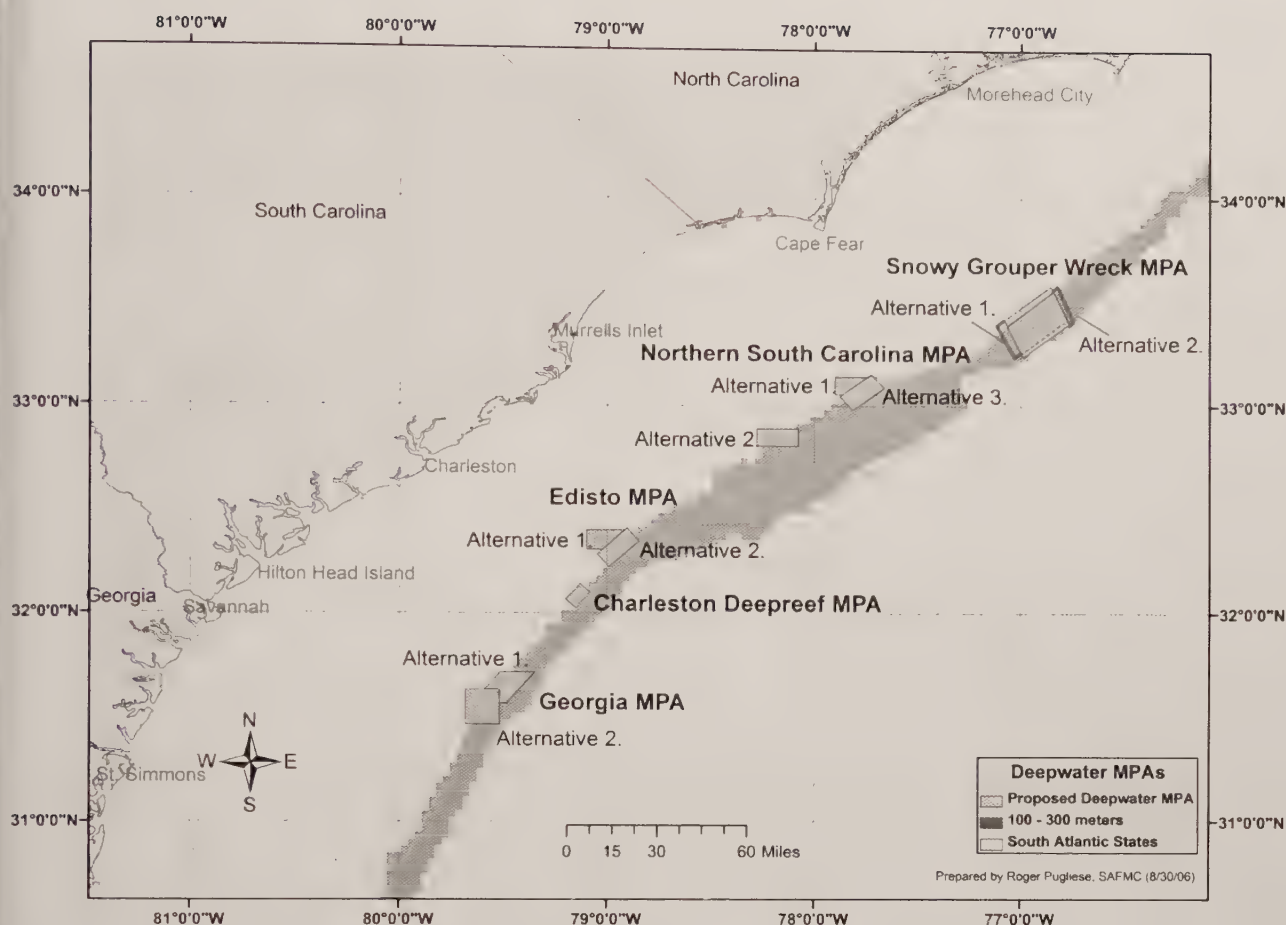


Figure 1.—Proposed Amendment 14 MPA's off the Carolinas and Georgia.

Table 2.—Proposed Amendment 14 MPA's off Florida.

MPA	Location and description
North Florida	Six alternatives, ranging from 10 nmi x 10 nmi to 22 nmi x 23 nmi, located from 43–60 nmi off the coast of northeast Florida. Alternatives 1, 2, and 4 are fished more heavily for mid-shelf SG species than Alternatives 3, 5, and 6. All six are sited in an area where significant rock and royal red shrimp trawling takes place.
St. Lucie Hump	One alternative, 2 nmi x 4 nmi, located 9 nmi SE of St. Lucie Inlet, Fla. Anecdotal information indicates site is habitat rich with deepwater species. Sited on active trolling grounds for pelagic species.
East Hump/Un-named Hump	One alternative, 5 nmi x 10 nmi, located 13 nmi off Long Key, Fla. Sited in an area that is habitat rich and heavily trolled for pelagic species.

This process is repeated until some level of group consensus is reached regarding the designated problem. Essential characteristics of the Delphi include anonymity, repetition, controlled feedback, and statistical summaries of group opinion.

The Delphi technique has many strengths relative to other decision-

making processes. Anonymity allows participants to freely communicate their opinions without fear of reprisal or alienation. Anonymity also helps to prevent situations where a dominant voice or position overly influences the responses of other panel members. The structured nature of the process allows a diverse group of experts to

communicate, posit subjective judgments, and come to a consensus lending credence to controversial solutions to complex problems which may not be attainable by analytical methods (Linstone and Turoff, 1975).

Another advantage is that a panel with a range of expertise, perspectives, and cognitive abilities can contribute individually at appropriate times when their particular input can be efficiently processed leading to a group solution to a problem that may have more complex facets than just their area of expertise (Stitt-Gohdes and Crews, 2004). With recent technological developments in communications and computing, a Delphi Conference (Linstone and Turoff, 1975) may allow a larger number of participants to contribute than face to face or tra-

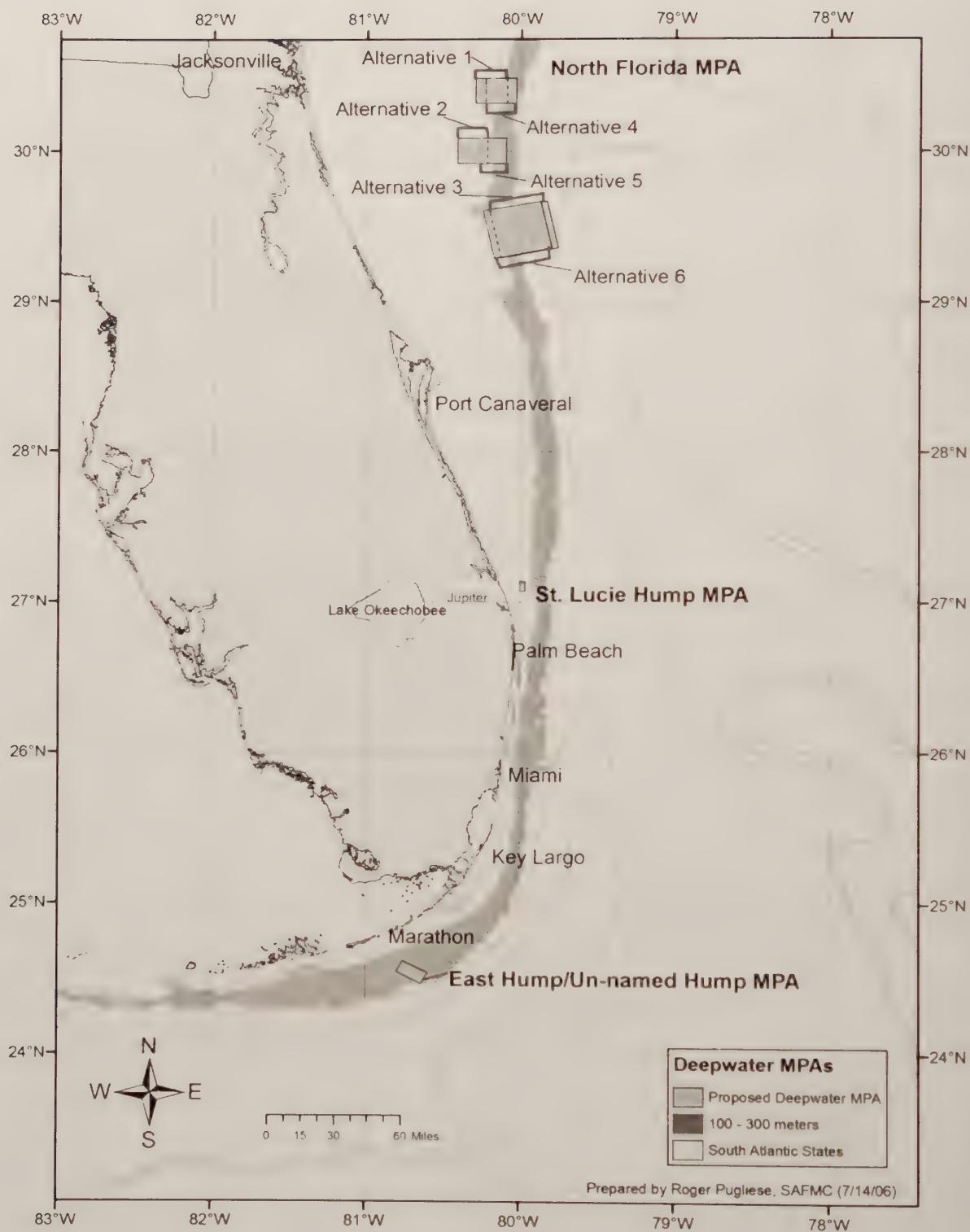


Figure 2.—Proposed Amendment 14 MPA's off Florida.

ditional conference and panel settings while also reducing the time needed to administer questionnaires and summarize feedback.

On the other hand, the Delphi technique does have weaknesses. Administrators wield considerable power and may inject personal biases into the process. For example, experts may be picked such that the panel is stacked towards a particular position of the issue at hand, while questionnaires, feedback summaries, and scoring methods can be engineered to steer results towards a predetermined consensus point. Failure to adequately explore disagreements and to allow each participant to appropriately present their feedback could lead to drop outs and an artificial consensus (Linstone and Turoff, 1975).

The possibility of groupthink leading to an irrational consensus should be of concern. While anonymity is an advantage of Delphi, the associated lack of accountability for panelists may lead to hasty or uninformed responses (Goodman, 1987). Though technological progress has led to advantages for Delphi in some situations, a traditional multi-round Delphi still takes considerable time and effort from administrators and participants; thus, full and active participation by the panel throughout the entire process may be difficult to attain.

The lack of refined spatial data relevant to the MPA's proposed in Amendment 14 offered a unique opportunity to apply the Delphi method in fisheries management. It was considered experimental, as no Delphi or consensus-oriented studies had at that time been carried out specifically to forecast net socioeconomic impact resulting from implementation of MPA's. However, since the completion of this Delphi study, economic valuations associated with alternative MPA sites in California state waters were calculated using a short-run comparative static model and a long-run dynamic bioeconomic model and were subsequently used in an iterative evaluation process to help determine preferred MPA's (White et al., 2012).

The Southeast Delphi Expert Panel

The name given to our Delphi experiment was the Southeast Delphi Expert Panel (SEDEP). SEDEP was conducted anonymously by email from 17 July 2006 to 30 Sept. 2006. For this panel, we recruited stakeholders with commercial and recreational (i.e., for-hire) fishing interests, as well as others with expertise covering biology, economics, and anthropology. Experts in these fields were initially identified and invited to participate based on years of active fishing experience (fishermen), published research (academics), and management experience (fishery managers) associated with the areas and species of interest in Amendment 14.

Experts initially targeted were also invited to suggest other colleagues within their own social network to participate in the study. Seventeen panelists, geographically dispersed from the Carolinas to the Florida Keys, agreed to participate. This group included five fishermen, three academics, and nine fishery managers. Of the original seventeen, twelve panelists participated in at least one round of SEDEP. This group included four fishermen, three academics, and five fishery managers.

Of the twelve, six self-identified as biologists, including three NMFS employees and three academics, four identified as fishermen, including two commercial and two for-hire, one identified as an anthropologist (NMFS employee), and one identified as an economist (state employee). Most had significant cross-knowledge about the biology associated with the proposed sites in Amendment 14 and the socioeconomic situations of dependent fishermen and their communities, as well as general knowledge of MPA's.

The majority of the participating experts also had experience with at least one of the sites, whether it was through actual fishing, biological research, or interaction with fishery stakeholders. These insights were treated as expert testimony and were systematically dis-

seminated to the rest of the panel, so that each panelist had some fundamental information about each of the proposed sites.

For the most part, all communication with the panelists and the moderation team was done through a third-party administrator via email. All emails sent to panelists used blind carbon copy, which is an email option which hides recipients' email addresses, and experts were assigned a random respondent number. This insured anonymity among panel members as well as between the panel and the moderation team. This was done to insure that there was no bias among the moderators as they evaluated qualitative responses from panelists.

Due to the complexity of quantifying socioeconomic effects, the moderation team did conduct telephone calls with individual panelists to aid in responses. Care was taken not to influence any responses, and since the impact analysis was purely quantitative, there was no opportunity to amend a respondent's impact scores due to mediator bias. Updates and final results were distributed in the same manner to the panel, using Word, Adobe Portable Document (PDF), and Excel formats.

SEDEP was conducted in three stages or rounds (Fig. 3). Round One was a Policy Delphi in which the panelists identified a comprehensive list of socioeconomic effects that potentially could be associated with the kinds of Type 2 MPA's that would be implemented by Amendment 14. This was a brainstorming session designed to produce strongly opposing views among the panelists. A Policy Delphi differs from a traditional Delphi, in that its final goal is to elicit differing viewpoints regarding some contentious issue, rather than to reach a consensus (Turoff, 1970). Thus, the role of Round One pertained more to policy analysis than decision making.

Round Two followed a more traditional Delphi approach. Its primary objective was to group and rank the most important of the socioeconomic effects identified in Round One. First,

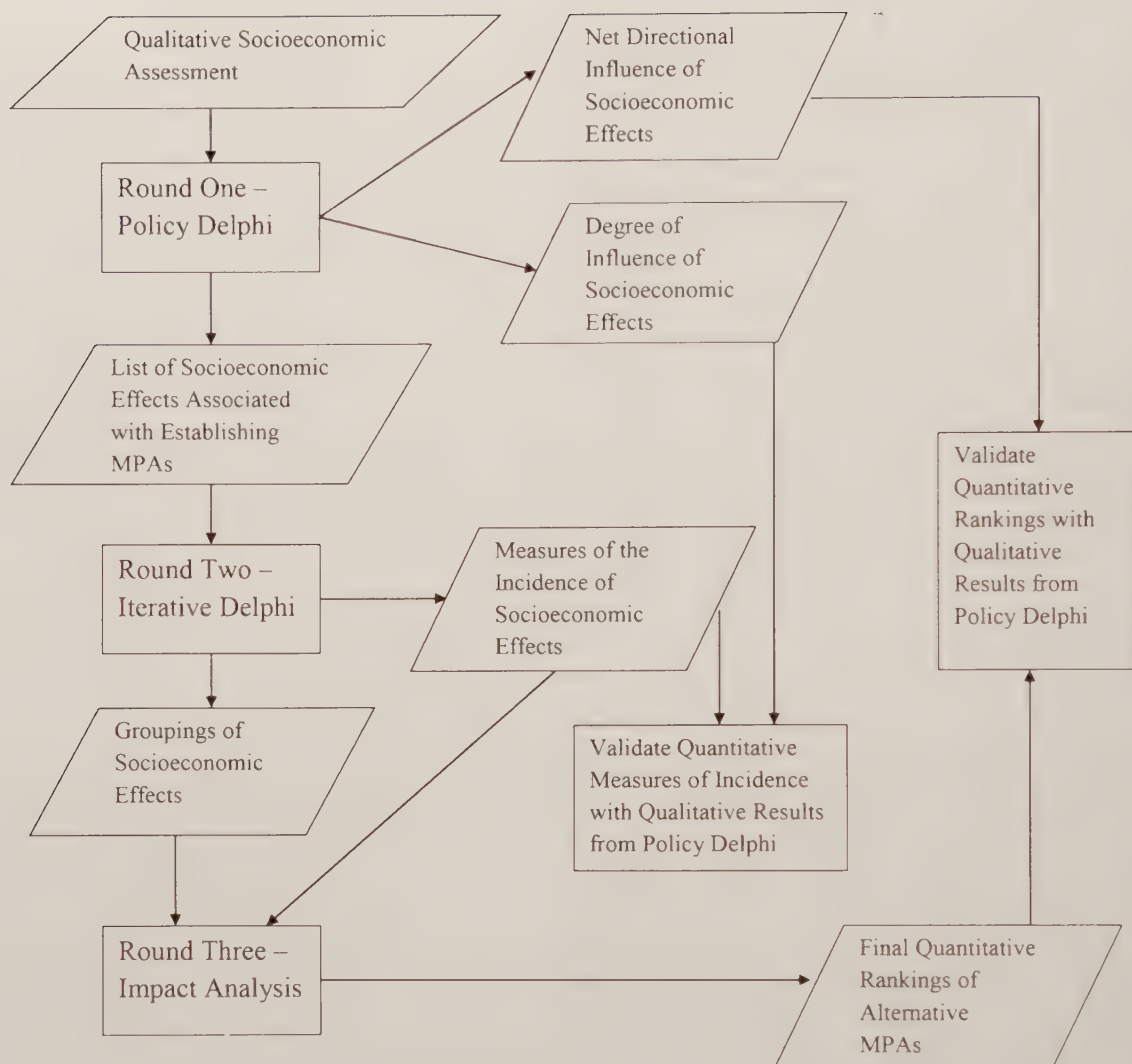


Figure 3.—Flowchart of the processes, inputs, and outputs associated with SEDEP.

panelists were asked to group individual effects on the basis of common characteristics. Four groupings of socioeconomic effects were identified based on the following common characteristics: management and administration of MPA's, influence of MPA's on commercial and recreational fishermen, community and regional effects, and influences on the ecosystem associated with future resource use. A time dimension was then introduced to distinguish short-term (<1 yr) effects of implementing a network of Type 2 MPA's from effects that would arise in the medium term (1–5 yr) and long

term (>5 yr).⁹ Finally, groups of effects were ranked in importance based on their expected overall impacts during each of the three time periods after implementation.

The primary objective of Round Three was to differentiate among alternative sites for each proposed MPA in Amendment 14, according to their socioeconomic impact on fishery stakeholders. We used a weighted scoring system based on the results from Rounds One and Two to achieve

⁹The length of the time frames was defined by the moderators and was not a product of panel consensus.

this objective. In Delphi terminology, this is considered an impact analysis.

Each panelist was asked to estimate the impact of each group of effects in each time period on a scale of -3 to 3, with a score of zero representing a neutral impact¹⁰ (Table 3). Overall impact scores for each grouping of effects in each time period were calculated with a probabilistic consensus model (PCM) that enabled us to test

¹⁰Another reason for a score of zero could have been that the positive and negative impacts associated with the different effects within a group canceled each other out. This was very possible, since the groupings were broadly defined.

Table 3.—Scoring of the Impact of Group Effects.

Score	Effect
-3	High negative impact
-2	Moderate negative impact
-1	Minimal negative impact
0	Neutral impact
+1	Minimal positive impact
+2	Moderate positive impact
+3	High positive impact

for agreement in responses among panelists (Romney et al., 1986).

We utilize PCM to reconstruct an “answer key” based on patterns of agreement among our expert panelists. The “answer key” represents forecasted socioeconomic impacts for groupings of effects in different time periods and is produced by the consensus model based on correlations among the original impact scores submitted by the panel and Bayesian statistical theory. The cultural consensus model is based on the premise that variation in knowledge among individuals can be attributed to cultural differentials, and allows us to test for differences in responses for subcultures of knowledge within the Delphi panel based on professional affiliation: biologists and nonbiologists.

Relative weights based on the rankings of effects from Round Two were used to calculate the overall weighted impact scores in each time period derived from PCM that were employed to compare the alternatives associated with the Amendment 14 MPA sites. The Wilcoxin Signed-Rank Test produces a nonparametric statistic that was used to formally test for differences in scores among the alternatives for each MPA site while we employed a Wilcoxin-Mann-Whitney nonparametric estimator to test differences between two independent samples from among Delphi subgroups (i.e., biologists and nonbiologists). The no-action alternative was not explicitly evaluated by the panelists and was defined to have a score of zero.

SEDEP Results

Submissions from all panelists were used in Round Three to rank the alternatives associated with each of

the individual MPA sites. However, a more detailed analysis of the results from all rounds shows cultural differences among these experts. Throughout SEDEP, we focused on two main stakeholder groups: biologists and nonbiologists. By comparing differences among these groups throughout the Delphi process, we were able to identify significant cultural differences among these stakeholders with respect to the proposed MPA’s over time as well as changes in individual positions over the course of the experiment.

Round One Results

Eleven experts participated in Round One. Effects with potential socioeconomic implications that would have a negative net directional influence identified by majority support on the panel included

- decreased catch levels;
- increased trip, search, and gear costs;
- increased costs to learn new fishing practices;
- redirected effort toward unprotected species;
- congestion effects and user conflicts;
- decreased personal safety;
- adverse community and social effects;
- income loss to local and regional economies;
- costs to maintain and enforce MPA’s; and
- costs for public outreach and education.

Effects with potential socioeconomic implications that would have a positive net directional influence identified by majority support on the panel included

- increased biomass and health of stocks;
- increased future catch levels and yields;
- replenishment, recruitment, and spillover in open areas;
- reduced variability in landings and revenue;
- hedge against future stock collapses;
- realized option and existence values;

- beneficial human community effects from stock reliability;
- improved environmental and habitat quality;
- ecosystem protection;
- reduced risk associated with stock assessments; and
- control areas for experimental biological research.

As expected, early in this round experts chose to comment primarily on their areas of expertise. Nonbiologists, mostly comprised of fishing interests, focused on the economic and social implications of MPA’s on the fishing industry and their communities, while the biologists generally focused on socioeconomic effects relating to stock conditions and ecosystem services.

As Round One progressed the panel began to refine and consolidate their views while focusing on the Amendment 14 MPA’s with the following conclusions receiving majority support from the panel:

- Displacement costs will be minimal or neutral due to the small size of the MPA’s and close proximity and knowledge of similar fishing grounds.
- Risks to personal safety will be neutral.
- Biological and ecosystem benefits will be minimal due to the small size of the MPA’s.
- Public resource management benefits will be minimal and will only be realized with adequate compliance and enforcement.

The following insights relative to the Amendment 14 MPA’s received strong minority support from experts on the panel:

- Sites that encroach into mid-shelf regions will inflict greater displacement costs to fishermen than those which encompass deep water only.
- As displaced commercial vessels move closer to shore, conflict with recreational vessels will increase.
- Unprotected species will be negatively impacted by displaced effort.
- A time dimension should be introduced to the analysis.

Table 4.—Groupings of socioeconomic effects resulting from the establishment of a network of Type 2 MPA's.

Administrative	Commercial, for-hire, and recreational	Community and social	Ecosystem
Conservation and fishery management goals	Catch levels and landings variation	Local economic and social effects	Ecosystem and habitat effects
Enforcement and monitoring	Trip-level search and other costs	Regional economic and social effects	Option and existence values
Education and awareness	Crowding and congestion	Associated employment (e.g. fish houses, dealers, bait and tackle shops)	Bycatch mortality
Improved stock assessments	Personal safety		Non-consumptive (non-use) opportunities
Insurance against stock collapse	Commercial and for-hire profitability and recreational enjoyment		Replenishment, abundance, and other stock effects
Improved knowledge of marine systems and effectiveness of MPA's	Replenishment, abundance, and other stock effects		Catch levels and landings variation
Ecosystem and habitat effects	Industry employment		

- Lack of baseline data on the habitat of the MPA's will hinder ex post evaluations.
- Non-use values will be positive but minimal.

As expected, the diversity of the experts resulted in an exhaustive list of potential effects with a fair degree of divergence regarding the influence of these effects. Negative effects would be realized mainly in the form of displacement effects on fishermen, and their families and communities that depend on them, with the possibility of management incurring some costs. However, due to the small size of the Amendment 14 MPA's and the availability of alternative fishing opportunities for displaced fishermen, displacement effects were likely to be minimal and observed only in the short term. Benefits were thought to be possible due to increases in longer-term catch levels, quality increases in the MPA and ecosystem, option and existence values, and management benefits. These benefits also were deemed to be minimal due to the small size of the Amendment 14 MPA's.

In general, both cultural subgroups consistently displayed majority support regarding the net directional influence of individual effects although conclusions about the level of influence of these effects specific to the Amendment 14 MPA's were mixed with nonbiologists concluding that the

potential economic and social consequences of MPA's to be more influential than biologists. The results alluded to cultural differences that would be revealed in later rounds. In general, consensus among the experts on most of the potential effects added validity to the qualitative responses elicited in this round and quantitative rankings derived in later rounds.

Round Two Results

At the end of Round One, the panel was fully engaged with the evaluation of the Amendment 14 MPA's; however, the comprehensive list of socioeconomic effects produced by the Policy Delphi was not compatible with a quantitative impact analysis. Therefore, the initial objective of Round Two was to organize the socioeconomic benefits and costs associated with spatial management into a manageable number of categories that could be used as criteria to compare alternative MPA's, while maintaining meaningful distinctions among the categories. The moderators offered four initial

groupings of effects to the panel at the beginning of Round Two: Administrative; Commercial, For-Hire, and Recreational; Community and Social; and, Ecosystem. The classification of the effects identified by the Policy Delphi is summarized in Table 4. Note that individual effects may be included under more than one group heading.

The ultimate objective of Round Two was to rank the most important of the socioeconomic effects based on their expected overall impact. To do so, panelists were asked to rank the groups listed in Table 4 based on their relative socioeconomic impact in the immediate, medium, and long terms. The rankings were then used to derive relative weights for each grouping of socioeconomic effects over time. The final rankings and weights of the groups by nine panelists are presented in Table 5.

Groups were ranked in importance on a one to four scale and were assigned points that corresponded to the ordered nature of the ranking system. Weights were calculated and interpreted as the relative importance that the panel attributed to each grouping of effects when determining the net socioeconomic impact of the implementation of a network of Type 2 MPA's. For example, one group of effects may be the most important determinant of socioeconomic impacts immediately after implementation; however, over time the socioeconomic implications of these effects may diminish as other factors become more consequential.

Weighting also implies that some groups of effects are more influential than others on the final determination of net socioeconomic impact. For instance, Table 5 suggests that within 1 year of implementation, community and social effects would be 60% as

Table 5.—Ranks and relative weights of four groupings of socioeconomic effects associated with the establishment of a network of Type 2 MPA's.

Group heading	Short term		Medium term		Long term	
	Rank	Weight	Rank	Weight	Rank	Weight
Administrative	2	0.95	1	1.00	2	0.84
Commercial, for-hire, and recreational	1	1.00	2	0.89	3	0.81
Community and social	4	0.60	4	0.64	4	0.59
Ecosystem	3	0.71	2	0.89	1	1.00

important as effects on the commercial, recreational, and for-hire sectors. Consequently, in the immediate term, socioeconomic effects associated with the commercial, for-hire, and recreational fishing sectors were deemed most influential; whereas, socioeconomic effects associated with public administrative issues and ecosystem changes were considered most dominant in the medium term and long term, respectively.

When analyzed over time the relative weights in Table 4 represent a forecast of the incidence of the groupings of socioeconomic effects associated with establishing MPA's. Some interesting trends were observed by comparing the incidence of the groups. First, community and social effects were considered less important than all other groups in all time periods. Second, as time goes on, the importance of effects on commercial, for-hire, and recreational fishermen becomes less relevant. Third, over time ecosystem effects become more important. Lastly, administrative effects were viewed as relatively important throughout all time periods. The weights, which are constant across MPA alternatives, also serve as a constraint by reducing variability in the calculated impact scores used for alternative site comparisons. For instance, if one expert feels strongly about a particular MPA, the constant weights will buffer individual prejudices.

In Round Two, changes in the perceptions of some of the panel members became evident. Nonbiologists explicitly took into account the small size of the proposed MPA's and generally merged to the consensus point that the overall financial impact, especially outside of the short term on fishermen and their communities, would be minimal. Biologists generally held onto their initial perspectives outlined in Round One that MPA's have significant socioeconomic impacts on stakeholders related to biological and ecosystem outcomes that outweigh the potential negative economic and social effects generated by protection throughout all time periods.

Round Three Results

In Round Three, the panel was asked to estimate the socioeconomic impact of each grouping produced in Round Two, on a scale of -3 to 3, for alternative MPA sites. Estimates were made for the short, medium, and long terms following MPA implementation. Given the small sample sizes, nonparametric estimators were used in conjunction with PCM to investigate cultural differences among biologists and nonbiologists regarding individual MPA options.

- Snowy Grouper Wreck MPA: In the short and medium terms, no-action scored higher than both alternatives. In the long term, both alternatives scored higher than no-action. Alternative 2 scored higher than Alternative 1 in all time periods. The differences in impact scores arose from one biologist and two nonbiologists forecasting larger negative impacts realized by the fishing sector for Alternative 1 relative to Alternative 2. Subcultures in knowledge regarding the socioeconomic consequences realized by the fishing sector in the short run were statistically significant for this MPA. Nonbiologists generally forecasted greater negative impacts than did biologists for both alternatives in the near term.
- Northern South Carolina MPA: In the short and medium terms, no-action scored higher than all three alternatives. In the long term, all three alternatives scored higher than no-action. Alternative 3 ranked lower than Alternatives 1 and 2 in all three time periods. Alternative 1 scored higher than Alternative 2 in the short and medium terms, while Alternative 2 scored higher than Alternative 1 in the long term. Nonparametric tests did not identify any significant cultural differences among biologists and nonbiologists for any of the alternatives for this MPA.
- Edisto MPA: In the short and medium terms, no-action scored higher than either alternative. In the long term, both Alternatives 1 and 2 scored higher than no-action. Alternative 1 scored higher than Alternative 2 in all time periods. Nonparametric tests suggest cultural differences regarding long-term impacts for administrative, fishing, ecosystem, and community effects may exist. Specifically, results suggest subcultures exist regarding knowledge about the long-term socioeconomic effects on the fishing sector for both alternatives as well as effects on communities associated with Alternative 1.
- Charleston Deep Reef MPA: In the short and medium terms, no-action scored higher than the alternative, but the alternative scored higher than no-action in the long term. Cultural differences related to Alternative 1 were not significant for any time periods.
- Georgia MPA: In the short and medium terms, no-action scored higher than both alternatives. In the long term, both alternatives scored higher than no-action. Alternative 1 scored higher than Alternative 2 in all time periods. Nonparametric tests suggest that subcultures in knowledge may exist in the long run for Alternative 1. Nonbiologists generally forecasted greater negative impacts than did biologists for both alternatives.
- Northern Florida MPA: In the short and medium terms, no-action scored higher than all six of the proposed sites. In the long term, Alternatives 2, 3, 4, and 6 scored higher than no-action. Alternatives 3 and 6 ranked higher than all other alternatives in the short and medium terms, while Alternative 2 scored higher than all other alternatives in the long term. Nonparametric tests suggest that subcultures in knowledge regarding the socioeconomic consequences associated with Alternatives 1 and 4 may exist for all time periods. Nonbiologists generally forecasted greater negative impacts than did biologists. In

the long term all weighted impact scores for members of the biological subculture were positive. However, only one non-biologist had a positive weighted impact score for both alternatives, due mainly to his/her forecast of high ecosystem benefits in the long term. Further tests suggest that subcultures associated with Alternative 2 may exist for all time periods, and subcultures may exist in the short and medium terms for Alternative 3. Nonbiologists generally forecasted greater negative impacts than did biologists for both alternatives.

- St. Lucie Hump MPA: In the short term, no-action scored higher than Alternative 1, but Alternative 1 scored higher in the medium and long terms. Subcultures in knowledge regarding the socioeconomic consequences associated with Alternative 1 may exist in the short and medium terms. Nonbiologists generally forecasted greater negative impacts than did biologists for Alternative 1. However, the nonbiologists' responses tended to be closer to the final weighted impact scores derived by the consensus model.
- East Hump MPA/Un-Named Hump: In the short term, no-action scored higher than Alternative 1, but Alternative 1 scored higher than no-action in the medium and long terms. Differences in cultural knowledge for Alternative 1 were not significant for any time periods.

The final rankings of alternative MPA sites from the Delphi experiment must be interpreted with caution, however. First, our response sizes for each impact analysis were relatively small and may not represent a true cross-section of knowledge regarding the Amendment 14 MPA's. Although our panel consisted of 12 individuals, usually only 7 or 8 responded regarding any specific MPA, with the identities of respondents differing among MPA's based on their local knowledge.

Also, it is important to realize that the panel reported impact scores for

the short, medium, and long term, and in most cases, it was not discernible whether they incorporated aspects of risk or other dynamic attributes into their scoring system. Consequently, each score for each alternative in a particular time period should be viewed independently of scores for the other time periods. We cannot justify or advocate a process of comparing alternatives by adding impact scores over time periods.

Conclusion

From a scientific perspective, we believe that the Delphi approach was superior to a simple, qualitative analysis of potential socioeconomic impacts from MPA's. The varied backgrounds of the panelists generated an extensive list of potential economic, community, ecosystem, and administrative effects which could arise due to the implementation of MPA's, demonstrating that the socioeconomic consequences associated with spatial closures are extensive, complicated to measure, and interconnected. However, there was a high degree of consensus among respondents in their scoring of the potential impacts, despite their varied backgrounds. In general, the panel concluded that in the near term the negative socioeconomic consequences impacted on the fishing industry and dependent communities would outweigh the short-term benefits of marine protection; thus, the no-action alternative usually was preferable to all alternatives. However, as the time frame increased, benefits from biological and ecosystem effects and mitigation of negative industry and community effects favored adoption of at least one alternative over no-action in the long term. It is likely that the diversity of the panel precluded a dominant bias from being systematically injected into the analysis.

Although a high degree of consensus was reached by the panel, differences in the cultural knowledge of the potential socioeconomic net impact on stakeholders was uncovered in a number of instances. Even though our sample sizes were small, biologists and

nonbiologists exhibited cultural differences for a few of the MPA options. Mainly, these differences centered on immediate-term negative effects on fishermen and their communities. This difference was identified subjectively in Rounds One and Two and statistically verified in Round Three for the following MPA's: Snowy Grouper Wreck, Edisto, Georgia, Northern Florida, and St. Lucie Hump.

It appears that by the end of the Delphi, nonbiologists had changed their perspective on the long-term benefits of MPA's by agreeing that the benefits in the future would outweigh the short-term displacement costs to industry and dependent communities. In general, biologists did not change their main positions during the process.

Of course, if data had been available, a quantitative comparison of the benefits and costs associated with each proposed MPA would have been preferred. However, the semi-quantitative Delphi approach represents a suitable alternative when data are not available. In addition, the Policy Delphi of Round One could be employed in other aspects of fishery management, for example, during discussion of the Council's Advisory Panels for future amendments. A Policy Delphi of this sort may be used as a precursor to committee activity, not so much to gain consensus on an issue, as to expose differing positions among varied constituents.

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Alaska Fisheries and Global Trade: Red King Crab, *Paralithodes camtschaticus*; Sockeye Salmon, *Oncorhynchus nerka*; and Walleye Pollock, *Gadus chalcogrammus*

MICHAEL DALTON and JEAN LEE

Introduction

Fisheries have always been global based on the ecology of stocks. In addition, the real value of fish-related world exports has grown at an average rate of nearly 4% each year over the past three decades (Fig. 1), according to fisheries data from the Food and Agriculture Organization of the United Nations (FAO¹). The growth in real value reflects a global trend in the physical volume of fish-related exports (i.e., metric tons), which according to FAO data¹, increased by more than 5% per year on average for the world over this period (Fig. 2). Together, these trends imply that prices, or the species composition of global catch and pro-

duction, or both, have changed in the past three decades. This article briefly evaluates these trends in the context of Alaska's commercial red king crab, *Paralithodes camtschaticus*; sockeye salmon, *Oncorhynchus nerka*; and walleye pollock, *Gadus chalcogrammus*, fisheries.

Red King Crab

The Bering Sea red king crab fishery has been the subject of much attention in recent years. The major world producers of red king crab are currently the United States and Russia, with Russia the main source of U.S. imports. According to FAO data¹, Russia's production of king crab was historically much higher (Fig. 3). In 2007, U.S. producers² confronted a large volume of relatively inexpensive

imports³ of Russian king crab (Fig. 4). This situation is an economic problem for U.S. producers because cheap imports can cause a decline in wholesale (i.e., producer) prices⁴ for Alaska's king crab domestically and abroad, which benefits U.S. consumers but may reduce industry profits (Fig. 5).

Since 2006, average prices in real dollars for king crab have rebounded to previous peaks, demonstrating the variability of global and domestic prices for king crab. The downward trend in U.S. prices that started after 2002 occurred during a period of decline in Russian production and before the rise in U.S. imports, which occurred after 2004. Factors other than the total amount of crab on the market, such as the international composition of demand, must therefore be considered to explain recent trends in market prices.

Maps showing U.S. export destinations of king crab back to 1983 may be viewed online.⁵ All U.S. king crab

¹FAO fisheries data include global export, import, and production data. These data were retrieved in May 2014 (www.fao.org/fishery/statistics/software/fishstat/en).

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²Data on Alaska ex-processor values and quantities are based on fish ticket reporting and Commercial Operator Annual Reports (COAR) administered by the State of Alaska. The analysis in this article is based on COAR data retrieved from the Alaska Fisheries Information Network (www.akfin.org) in May 2014, before price data for 2013 were available. Consequently, the time series for Alaska end in 2012. Records in COAR data were summed for red king crab; golden king crab, *Lithodes aequispinus*; and blue king crab, *P. platypus*, to form a time series for all king crab to match the level of aggregation in U.S. trade data, which do not identify king crab to species.

³Data on U.S. exports and imports were taken from the Merchandise Trade Statistics administered by U.S. Census Bureau based on 10-digit harmonized system (HS) codes for seafood commodities. These data were retrieved from the Trade Policy Information System (TPIS, tpis.trade.gov) in September 2013 and May 2014. These data record exports from each U.S. customs district (e.g., Anchorage, Seattle) to partner countries.

⁴The term "price" is used loosely in this article and refers to one of various price indices that are used. Each is defined generally as the sum of revenues over a set of fish (or crab) products (e.g., whole fish or fillets) divided by the total weight of those products (i.e., unit-value). Real values including prices are calculated using a producer price index (commodities) from the U.S. Bureau of Labor Statistics, series WPU0223, Unprocessed and packaged fish (<http://www.bls.gov/ppi>). The base year is 2012 for all real values.

⁵Maps in this article are the frame for year 2012 taken from a set of dynamic maps showing U.S. exports over time in metric tons of Alaska mack-

ABSTRACT—Wholesale revenues for seafood products from Alaska's red king crab, *Paralithodes camtschaticus*; sockeye salmon, *Oncorhynchus nerka*; and walleye pollock, *Gadus chalcogrammus*, fisheries in Alaska were greater than \$2 billion dollars in 2012 and more than half of this amount came from exports. Globally, red king crab from Alaska competes with red king crab from Russia, and market prices are highly variable. Alaska's walleye pollock producers also compete

with Russian producers, though prices are less variable than with king crab. The United States imports large amounts of farmed Atlantic salmon, *Salmo salar*, from Canada. In exchange, Canada was the top export destination for Alaska's sockeye salmon in 2012 and number two (after Japan) for Alaska's king crab. Wholesale prices for Alaska's sockeye followed import prices of farmed Atlantic salmon from Canada until 2008, and then increased relative to import prices.

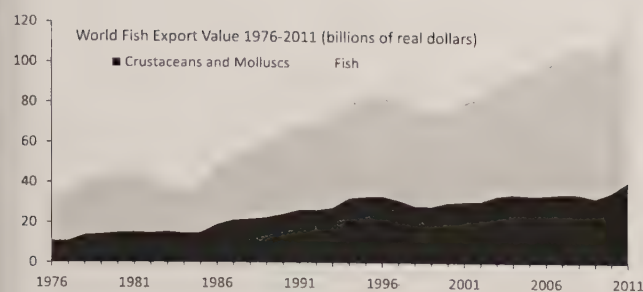


Figure 1.—World export value of crustaceans, mollusks, and fish (Source: FAO).



Figure 2.—World export quantity of crustaceans, mollusks, and fish (Source: FAO).

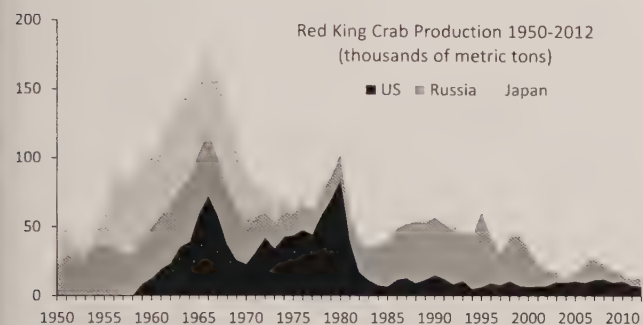


Figure 3.—World production of red king crab (Source: FAO).



Figure 4.—Alaska king crab production and U.S. trade (Source: COAR, TPIS).



Figure 5.—U.S. king crab prices (Source: COAR, TPIS).

erel, *Pleurogrammus monopterygius*; red king crab; Pacific ocean perch, *Sebastes alutus*; rock sole, *Lepidopsetta bilineata* and *L. polyxystra*; sablefish, *Anoplopoma fimbria*; sockeye salmon; walleye pollock; and yellowfin sole, *Limanda aspera*. Animations of these dynamic maps for U.S. exports of Alaska seafood products are presented online (www.afsc.noaa.gov/REFM/Socioeconomics/Projects/AFGT.php). The starting year of each animation depends on the year the relevant HS code was created. For king crab, sockeye salmon, and walleye pollock, the starting year is presented in the titles of Figure 6, 11, and 16, respectively. For example, TPIS has trade statistics for king crab going back to 1983. Note that exports to Canada in these maps are represented by the port of Come By Chance in the province of Newfoundland and Labrador.

is harvested off the coast of Alaska. In 2012, the majority of U.S. exports of king crab were shipped via Anchorage and Seattle mainly to Japan, Canada, China, and Europe, with smaller amounts shipped to tourist areas in Southeast Asia and the Caribbean (Fig.

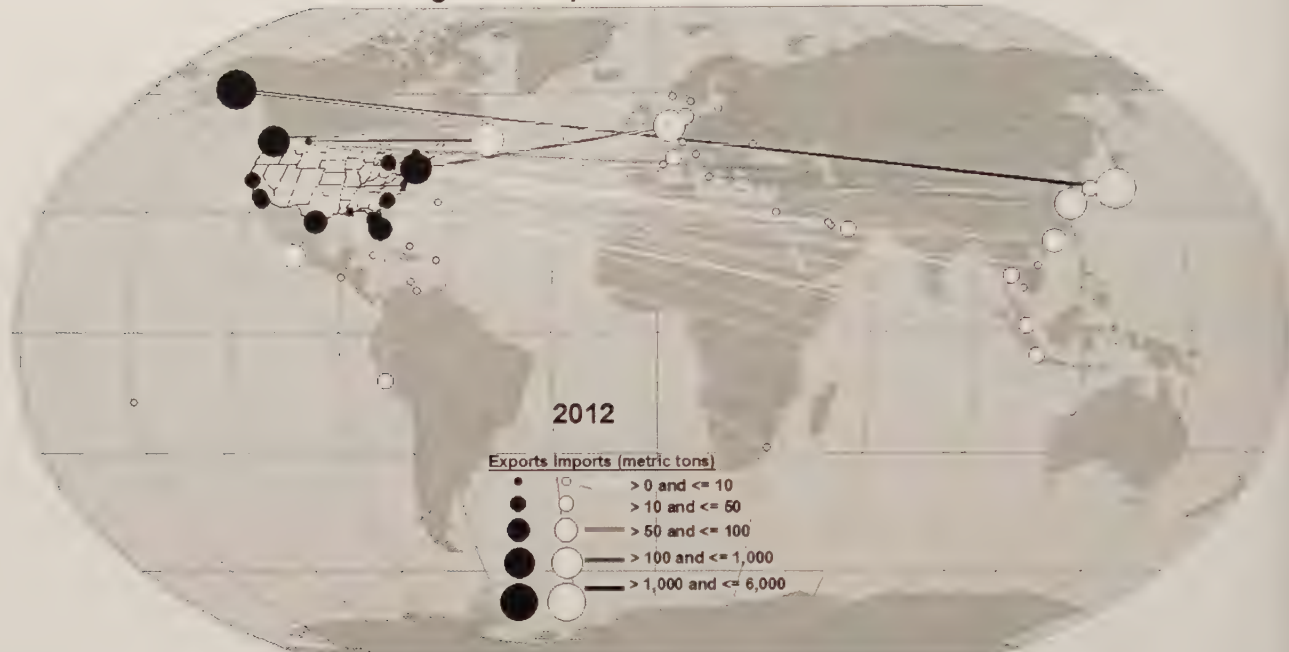
This choice was deliberate. Locating import symbols at the better known port of Vancouver, Canada, interfered with export symbols for Seattle. Likewise, locating symbols at the port of Toronto interfered with export symbols for U.S. customs districts close to the border (e.g., New York).

6). The overall picture shows that large quantities of Alaska king crab are shipped all over the world, with major markets in Asia, Canada, and Europe providing a valuable source of income.

Sockeye Salmon

The United States is a major producer of wild Pacific salmon which includes Chinook, *O. tshawytscha*; chum, *O. keta*; coho, *O. kisutch*; pink, *O. gorbuscha*; and sockeye salmon (Fig. 7). Alaska has the largest salmon

U.S. King Crab Exports to the World, 1983-2012



Source: U.S. Merchandise Trade Statistics. GIS: Alaska Fisheries Science Center (michael.dalton@noaa.gov)

Figure 6.—U.S. king crab exports to the world in 2012 (Source: TPIS time series from 1983–2012).

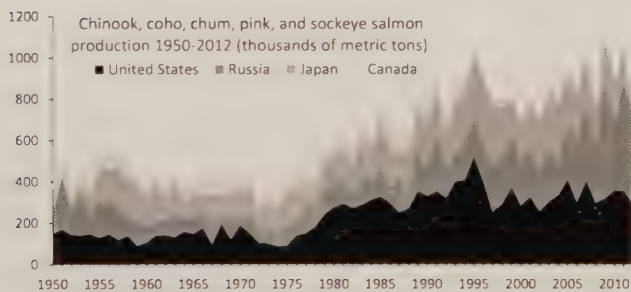


Figure 7.—Global wild salmon production (Source: FAO).



Figure 8.—Alaska salmon wholesale value (Source: COAR).

production of any state, and much of Alaska's revenues come from sockeye (Fig. 8). In terms of total revenue in Alaska from a single species, sockeye salmon ranks second behind walleye pollock.

The United States imports large quantities of farmed Atlantic salmon, mainly from Canada (Fig. 9). Wholesale prices for Alaska sockeye have tracked prices for U.S. imports of farmed Atlantic salmon, but recently these price series diverged (Fig. 10). In 2012, the majority of U.S. exports of

sockeye salmon were shipped via Anchorage and Seattle mainly to Japan, Canada, and Europe (Fig. 11).

Canada has been the main source of farmed Atlantic salmon imported by the United States (Fig. 9), as well as a major consumer of Alaska sockeye salmon (Fig. 11), and Alaska king crab (Fig. 6). In 2012, Canada was the top destination for U.S. exports of fresh and frozen sockeye salmon, with over a quarter of the export volume (Fig. 11). In addition, one-fifth of U.S. exports of frozen king crab went to Can-

ada (Fig. 6). This exchange of farmed salmon for wild salmon and crab presents an interesting pattern of trade between the United States and Canada.

Walleye Pollock

Real wholesale revenues for Alaska's processors from walleye pollock averaged nearly \$1.4 billion per year from 2003 to 2012, close to three times more than sockeye salmon, the species with the second highest revenues during this period (Fig. 12). Globally, the United States was the top pollock

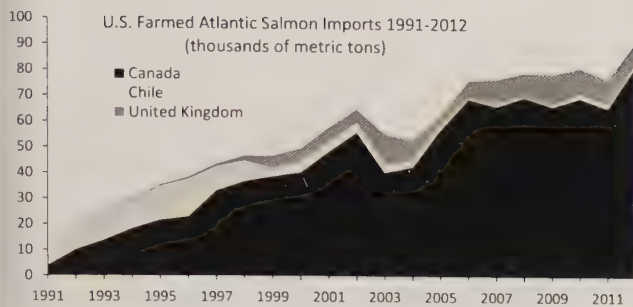


Figure 9.—U.S. imports of farmed Atlantic salmon (Source: TPIS).

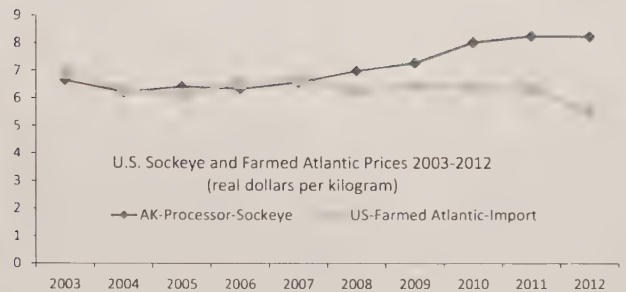
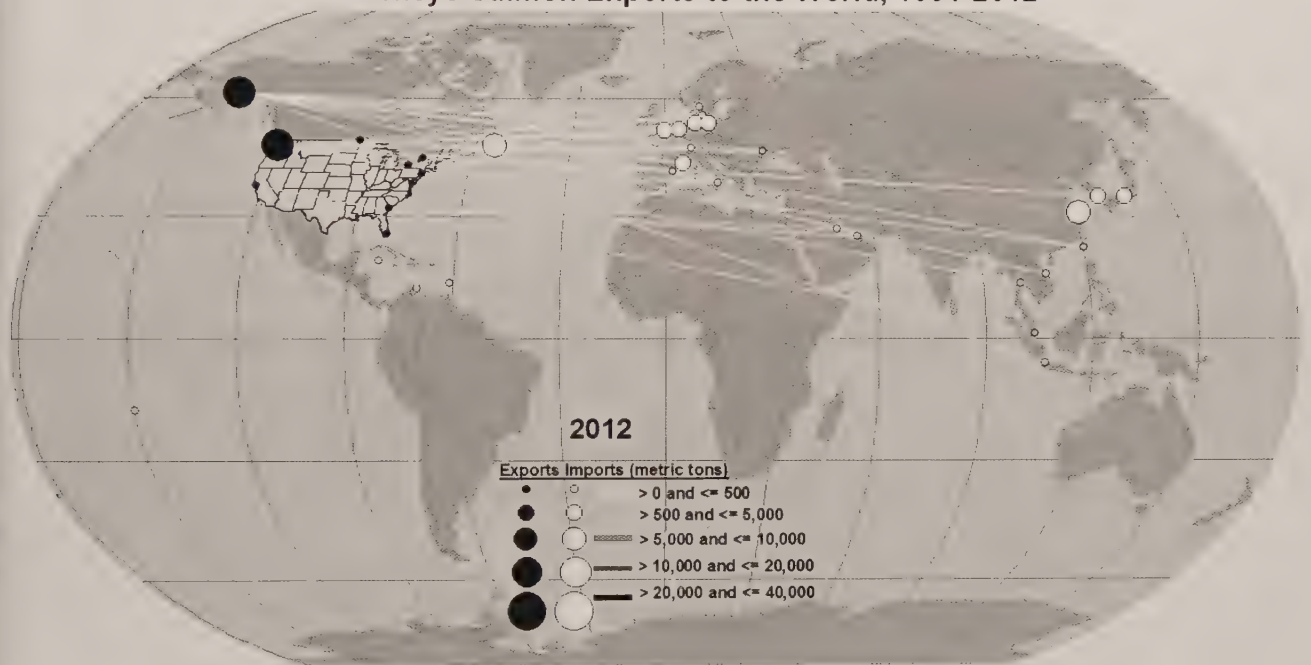


Figure 10.—Prices for Alaska sockeye and U.S. farmed Atlantic salmon imports (Source: COAR, TPIS).

U.S. Sockeye Salmon Exports to the World, 1991-2012



Source: U.S. Merchandise Trade Statistics. GIS: Alaska Fisheries Science Center (michael.dalton@noaa.gov)

Figure 11.—U.S. exports of sockeye salmon to the world in 2012 (Source: TPIS time series from 1991–2012).

producer between 2000 and 2008, but, historically, Russia has produced more (Fig. 13). The three main products of Alaska pollock are fillets, roe (eggs), and surimi (paste). Production and exports of each product decreased after 2007 (Fig. 14). Prices for roe have declined since 2003, while prices for fillets and surimi have fluctuated without exhibiting a clear trend (Fig. 15). The global distribution of U.S. exports of

walleye pollock (Fig. 16) shows the importance of markets in Asia and Europe (and, to a lesser extent, Canada) in the international demand for seafood products from Alaska.

Conclusions

This article describes the historical role and recent state of global markets in Alaska red king crab, sockeye salmon, and walleye pollock fisheries.

In the first case, Alaska crab was seen to compete directly with the Russian crab industry, which historically has had high production levels and exports to the United States.

The second case compared wholesale prices received by processors of Alaska sockeye salmon to the global rise in farmed Atlantic salmon. In this case, the United States was seen to export about half of its wild sock-



Figure 12.—Alaska top-ten species by wholesale value (Source: COAR).

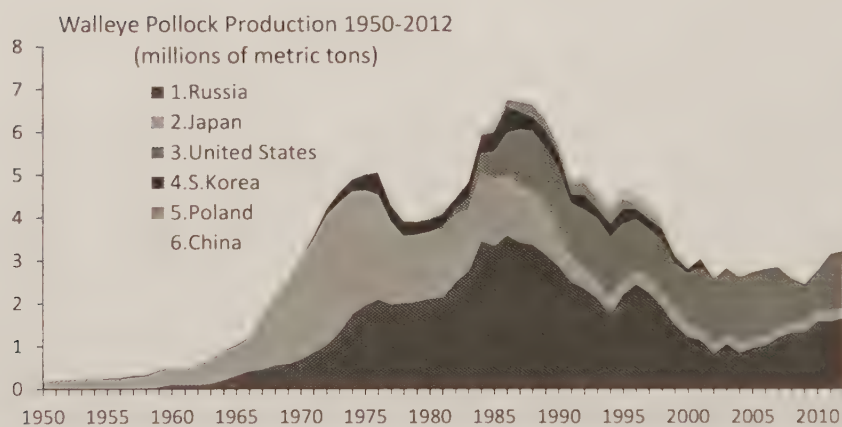


Figure 13.—World walleye pollock production (Source: FAO).



Figure 14.—U.S. consumption and exports of walleye pollock (Source: COAR, TPIS).

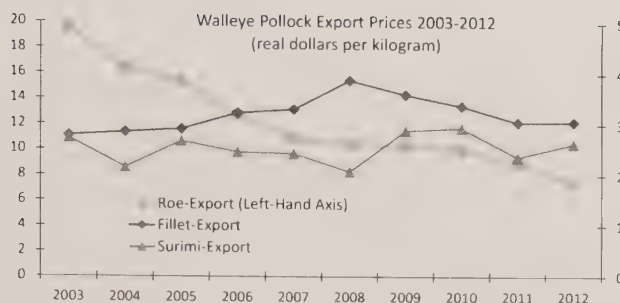


Figure 15.—Prices for exports of Alaska walleye pollock (Source: TPIS).

U.S. Alaska Pollock Exports to the World, 1983-2012



Source: U.S. Merchandise Trade Statistics, GIS: Alaska Fisheries Science Center (michael.dalton@noaa.gov)

Figure 16.—U.S. exports of Alaska walleye pollock to the world in 2012 (Source: TPIS time series from 1983–2012).

eye production, with much of it going to Canada in exchange for imports of farmed Atlantic salmon. These commodities were exchanged at roughly equal prices until 2008, when U.S. producer prices for sockeye began increasing relative to import prices for farmed Atlantic salmon.

The third case gave a brief overview of the interrelated markets for fillets, surimi, and roe from walleye pollock. In each case, global trade and interna-

tional market conditions played an important role. The historical relationship between sockeye prices and imports of farmed Atlantic salmon, as well as the variability in prices of red king crab and roe from walleye pollock, are additional evidence of effects of global markets on Alaska fisheries.

Although the global trend in seafood markets has been towards more exports, both sockeye and red king crab production in the United States are ex-

ceptions. The share of exports in U.S. sockeye production has been fairly stable, fluctuating between 40% and 50% of production since 2003. The U.S. export share of king crab does not exhibit a trend since 2003 and has been highly variable, fluctuating as much as 40–70% in consecutive years; the average share for 2003–12 was slightly less than 60%.

Walleye pollock roe is a low volume/high value product, and nearly all

of it is exported. The U.S. export share of surimi production climbed from less than 70% in 2003 to over 90% in 2012. Japan is the main export market for roe and surimi, and fillets are shipped mainly to Europe and Canada, plus a variety of smaller markets in Asia, Africa, and Latin America. Export shares for fillets exhibited an up-

ward trend during 2003–12, to about 60% in 2012 from less than 50% in 2003.

International trade is an important part of the Alaska economy, and crab, salmon, and groundfish fisheries all contribute. The future directions of these fisheries will probably be diverse, but trends in global seafood

markets seem certain to be a common influence.

Acknowledgments

The authors thank two anonymous reviewers and the editor for many helpful comments. The primary author is responsible for any remaining errors.

Excess Harvesting Capacity in Federally Managed Commercial Fisheries: Results from Two U.S. Reports

JOSEPH TERRY and MINLING PAN

This extended abstract presents information from the following two reports on excess harvesting capacity that NOAA's National Marine Fisheries Service (NMFS) completed in 2008: 1) National Assessment of Excess Harvesting Capacity in Federally Managed Commercial Fisheries¹ and 2) Excess Harvesting Capacity in U.S. Fisheries: A Report to Congress². Both reports are the products of a collaborative effort that included contributions by economists and others at all of the NMFS Fisheries Science Centers and Regional Offices, the NMFS Offices of Science and Technology, Sustainable Fisheries, and International Affairs, the eight Regional Fishery Management Councils, and three universities.

The National Assessment was conducted in part to meet a commitment in the United States National Plan of Action for the Management of Fishing Capacity³, which NMFS prepared in 2004 in response to 1) NMFS stewardship responsibilities; 2) the United

Nations Food and Agriculture Organization (FAO) International Plan of Action for the Management of Fishing Capacity⁴; and 3) the national and international concerns that overcapacity, overfishing, and other often co-occurring undesirable outcomes of a common underlying management problem prevent the attainment of the objectives for sustainable fisheries.

The Report to Congress was required by the Magnuson-Stevens Fishery Conservation and Management Act (MSA) as amended in January 2007. The National Assessment was used in preparing the Report to Congress. The Report to Congress includes harvesting capacity assessments for 25 fisheries, 60 fleets, and 127 species groups; identifies and described the fisheries with the most severe examples of excess harvesting capacity; and discusses measures to reduce excess harvesting capacity.

Presented here are the definitions of harvesting capacity, excess capacity, and overcapacity used in the two reports; a summary of the method used to estimate harvesting capacity; and some of the findings and policy recommendations in the two reports.

The reports define "excess harvesting capacity" to mean "too much" harvesting capacity and uses the following three measures or indicators of excess harvesting capacity:

- 1) Excess capacity: the difference between capacity and actual harvest,
- 2) Overcapacity: the difference between capacity and the harvest quota, and
- 3) Overharvest: the difference be-

tween the actual harvest and the harvest quota.

Data envelopment analysis (DEA), trip-level catch data, and data on the physical characteristics of fishing vessels were used to estimate harvesting capacity by species groups, trip, and quarter (or other multi-month period). Those estimates were aggregated to provide estimates of harvesting capacity, excess capacity, overcapacity, and overharvest by fishery and species group, as well as estimates of harvesting capacity and excess capacity by fleet.

DEA is a mathematical programming approach that has been used to estimate capacity for a variety of industries and fisheries. Both reports include 11 basic terms of reference and constraints for the estimates that are intended to put the estimates in the appropriate context and to clarify the nature of the estimates, thereby increasing the probability that the estimates will be interpreted appropriately.

The two reports indicate that the excess capacity, overcapacity, and overharvest rates vary considerably among regions and fisheries, among fisheries themselves, and even among fleets and species groups within individual fisheries. High rates of excess capacity and overcapacity were accompanied by species groups that were subject to overfishing in 2004 in some federally managed commercial fisheries. In other fisheries with high rates of excess capacity and overcapacity, effective management of the use of harvesting capacity or other factors prevented overfishing, but they often did not prevent all the other co-occurring undesirable outcomes.

¹Available online (www.nmfs.noaa.gov/ocs/inafac/meetings/2008_11/docs/excess_harvesting_capacity_in_us_fisheries_appendix_c.pdf).

²Available online (www.nmfs.noaa.gov/ocs/mfac/meetings/2008_11/docs/excess_harvesting_capacity_in_us_fisheries_report.pdf).

³Available online (www.nmfs.noaa.gov/ia/resources/publications/ccrf/npoa_management-fishingcapacity2004.pdf).

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⁴Available online (<http://www.fao.org/docrep/006/X3170E/x3170e04.htm>).

A high excess capacity rate indicates that the actual harvest in 2004 could have been taken by much smaller fleets and, therefore, at a lower cost, if the fleets had operated at capacity. A smaller fleet could have consisted of fewer vessels, fishing vessels that on average had less harvesting capacity, or both. The cost reductions could have included lower operating costs and annual fixed costs as well as reduced costs associated with, for example, bycatch, impacts on habitat, unsafe fishing practices, and fishery management.

The reports emphasize that, when they occur, overcapacity and overfishing are just two of the often co-occurring undesirable outcomes of a common management problem that prevents the attainment of the objectives for sustainable fisheries. The other undesirable outcomes include high levels of bycatch, adverse impacts on habitat, substandard vessel safety, lower product quality, poor economic performance, less viable fishing communities, noncompliance with regulations, and a fishery management regime that is unnecessarily complex, contentious, and costly.

The common underlying management problem is that, in the absence of well-defined and secure harvest privileges, the race for fish typically is used to allocate the allowable catch among competing fishermen, and the race for fish provides incentives for individual fishermen to increase harvesting ca-

capacity, to contribute to overfishing, and to take other actions that prevent the attainment of the objectives for sustainable fisheries. The severity of the undesirable results of this problem can be increased by inadequate information, monitoring, and enforcement, which, in part, can be due to the underlying problem. Basically, without well-defined and secure harvest privileges, the interests of individual fishermen are not aligned with the objectives for sustainable fisheries and fishermen do not have sufficient incentives to support investments in the conservation and management of fishery resources.

Based on the two reports, NMFS found that

- 1) It is possible, but typically not practical, to prevent overfishing by managing the level of harvesting capacity without also managing the use of harvesting capacity.
 - 2) Efforts to address the often co-occurring undesirable outcomes individually without addressing the common underlying management problem often have increased the severity of those outcomes and are likely to fail.
 - 3) Fishery management would be improved by initiating or accelerating efforts to identify and implement feasible catch share programs that reflect fishery-specific conditions, objectives, and fishery management capabilities and that will assist in ending/pre-
- venting overfishing, recovering overfished species groups within mandated schedules, managing the level and use of harvesting capacity more effectively, and decreasing the severity of the other often co-occurring undesirable outcomes by addressing the common underlying management problem.
- 4) The cost of providing adequate monitoring of total catch by species group is a critical factor in determining if an effective catch-share program is feasible for a specific fishery or fleet.
 - 5) The number, size, and horsepower of fishing vessels are some of the determinants of harvesting capacity, but they are not measures of harvesting capacity.

Portions of this abstract were earlier presented in Joseph Terry and Minling Pan. 2008. Findings of Two Recent U.S. Reports on Excess Harvesting Capacity in Federally Managed Commercial Fisheries. *In* Ann L. Shriver (Compiler), Proceedings of the Fourteenth Biennial Conference of the International Institute of Fisheries Economics & Trade, July 22-25, 2008, Nha Trang, Vietnam: Achieving a Sustainable Future: Managing Aquaculture, Fishing, Trade and Development, 12 p. International Institute of Fisheries Economics and Trade, Corvallis, Oreg., (online at <http://ir.library.oregonstate.edu/xmlui/bitstream/handle/1957/37737/360.pdf?sequence=1>).

Economics and the Endangered Species Act: Critical Habitat Designation for Pacific Northwest Salmon and Steelhead

MARK L. PLUMMER

Under the Endangered Species Act (ESA), NOAA's National Marine Fisheries Service (NMFS) is responsible for protecting and recovering species of marine fish, mammals, and plants that it determines to be in danger of extinction. As one of its responsibilities, the agency designates critical habitat for these species. Critical habitat consists of areas determined to have biological or physical features important to the conservation of the species. In areas designated as critical habitat, federal agencies must ensure that their actions do not adversely modify the habitat.

Mark Plummer (1954-2014) was with the Conservation Biology Division, Northwest Fisheries Science Center, National Marine Fisheries Service, NOAA, 2725 Montlake Blvd. East, Seattle, WA 98112-2097. In 2015 the NWFS honored his career with a memorial symposium (https://www.nwfsc.noaa.gov/news/events/symposia/mark_plummer/). The views expressed in this paper were those of the author and do not necessarily represent the position of the National Marine Fisheries Service, NOAA.

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The process for designating critical habitat is unusual in that it actually requires the consideration of economic impacts. The ESA gives NMFS the option to exclude individual areas from designation if the costs of designation outweigh the benefits of designation. The costs stem from the economic costs of changing federal activities to comply with the ESA in this regard, while the benefits come from the additional conservation achieved in an area that has been designated.

For west coast Pacific salmon, *Oncorhynchus* spp., and steelhead trout, *Oncorhynchus mykiss*, listed under the ESA, NMFS devised a framework to balance the economic costs and conservation benefits of critical habitat designation. NMFS used watershed units as mapped by the U.S. Geological Survey to define the individual areas for consideration.

For each watershed, an estimate was made of the economic costs of designation, which came from considering how the designation would affect ten types of federal activities that poten-

tially occurred in a watershed. Teams of biologists then determined the conservation benefit of designation, expressed as a relative score (high, medium, low) for the potential value of protecting the watershed to conserve the species.

Finally, a threshold cost level was chosen that governed the process for excluding a watershed, with higher thresholds chosen for higher levels of conservation benefit. If the estimated costs in a watershed were greater than the appropriate threshold, the watershed was then eligible for exclusion. This process enabled the agency to identify and exclude potential critical habitat areas that entailed high economic costs and low conservation benefits, making the designation of critical habitat more cost-effective (Plummer, 2007). Following this approach, NMFS excluded 106 watersheds from critical habitat designation.

Plummer, M. 2007. Welcome to the data-poor real world: incorporating benefit-cost principles into environmental policymaking. *Res. Law Econ.* 23:103-130.

Editorial Guidelines for the *Marine Fisheries Review*

The *Marine Fisheries Review* publishes review articles, original research reports, significant progress reports, technical notes, and news articles on fisheries science, engineering, and economics, commercial and recreational fisheries, marine mammal studies, aquaculture, and U.S. and foreign fisheries developments. Emphasis, however, is on in-depth review articles and practical or applied aspects of marine fisheries rather than pure research.

Preferred paper length ranges from 4 to 12 printed pages (about 10-40 manuscript pages), although shorter and longer papers are sometimes accepted. Papers are normally printed within 4-6 months of acceptance. Publication is hastened when manuscripts conform to the following recommended guidelines.

The Manuscript

Submission of a manuscript to the *Marine Fisheries Review* implies that the manuscript is the author's own work, has not been submitted for publication elsewhere, and is ready for publication as submitted. Commerce Department personnel should submit papers under a completed NOAA Form 25-700 (available from the SPO website).

Manuscripts must be double-spaced throughout, and a complete manuscript normally includes a title page, a short abstract, text, literature citations, tables, figure legends, footnotes, and the figures. The title page should carry the title and the name, department, institution or other affiliation, and complete address (plus current address if different) of the author(s). An "Acknowledgments" section, if needed, may be placed at the end of the text. Use of appendices is discouraged.

Abstract and Headings

Keep titles, headings, subheadings, and the abstract short and clear. Because abstracts are circulated by abstracting agencies, it is important that they represent the research clearly and concisely. Headings within each section must be short, reflect a logical sequence, and follow the rules of multiple subdivision (i.e., there can be no subdivision without at least two items).

Style

The entire text should be intelligible to interdisciplinary readers; therefore, all ac-

ronyms, abbreviations, and technical terms should be spelled out the first time they are mentioned. The scientific names of species must be written out the first time they are mentioned; subsequent mention of scientific names may be abbreviated. Follow the U.S. Government Printing Office Style Manual (2008 ed.) and the Scientific Style and Format: the CSE Manual for Authors, Editors, and Publishers (2014, 8th ed.) published by the Council of Science Editors for editorial style, and the most current issue of the American Fisheries Society's Common and Scientific Names of Fishes from the United States and Canada for fish nomenclature. Only journal titles, scientific names (genera and species), and vessel names should be italicized. Dates should be written as follows: 11 November 2013. Measurements should be expressed in metric units, e.g., metric tons as (t); other equivalent units may also be listed in parenthesis. Common abbreviations and symbols such as mm, m, g, ml, mg, and °C (without periods) may be used with numerals. The numeral one (1) should be typed as a one, not as a lower-case el (l). Write out the numbers zero through nine unless they form part of measurement units (e.g., nine fish but 9 mm).

Footnotes

Footnotes should not be embedded within the text document. They must be numbered with Arabic numerals and listed separately. Footnote all personal communications, unpublished data, and unpublished manuscripts with full address of the communicator or author, or, as in the case of unpublished data, where the data are on file. Authors are advised to avoid references to nonstandard (gray) literature, such as internal, project, processed, or administrative reports, wherever possible. Where these references are used, please include where they may be located (website or public depository).

Tables

Tables should be printed separately and double-spaced. Tables should not be excessive in size and must be cited in numerical order in the text. Headings should be short but ample enough to allow the table to be intelligible on its own. All unusual symbols must be explained in the table heading. Other incidental comments may be foot-

noted with Arabic numerals. Because tables are typeset, they need only be submitted typed and formatted, with double-spaced legends. Zeros should precede all decimal points for values less than one. Table headings and format should be consistent; do not use vertical rules.

Literature Cited

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